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TRAINING METHODOLOGY FOR LOGISTIC DECISION MAKING

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This report has been reviewed and is approved for publication.

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Logistics units must ensure that core and augmentee personnel are fully trained in the combat-critical skill of complex decision making. At present, training consists of expensive, manpower-intensive exercises, which afford only sporadic training opportunities. The need exists for more accessible, more affordable, and less manpower-intensive training. Logistics Command and Control (LC2) technology makes use of desktop computer hardware and software to produce simulation environments. Within these environments, personnel can experience real-world problems. The objective of this research is to design, develop, and test an experimental desktop decision trainer, incorporating simulation environments allowing for the practice of decision-making skills before, during, and after field exercises. This report documents the derivation of the instructional strategy and decision-making modeling approach for training decision-making skills.

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PREFACE

This report describes the development of instructional strategies for training complex decision-making skills to Logistics Command and Control (LC^2) personnel. The work was performed in support of the "Desktop Training for Logistics Command and Control (LC^2)" research and development effort. This project is being accomplished under Contract No. F33615-91-C-0007, with Systems Engineering Associates (SEA), San Diego, CA. Management of this effort is provided by the Armstrong Laboratory, Human Resources Directorate, Technical Training Research Division, Instructional Systems Branch (AL/HRTD).

SUMMARY

Logistics Command and Control (LC^2) units must ensure that core and augmentee personnel are fully trained in the critical combat skill of decision making. However, existing training capabilities are viewed as inadequate. They consist primarily of expensive and manpower-intensive exercises which afford only sporadic training opportunities; consequently they are insufficient in ensuring personnel achieve and maintain the skill levels required for successful combat operations. Thus, the need for more accessible, more affordable, and less manpower-intensive training continues to exist.

In May 1989, the Air Force Logistics Plans and Programs Directorate (HQ USAF/LGX) requested that the Air Force Human Resources Directorate (HR) develop an improved training technology for Logistics Command and Control Centers throughout the United States Air Force (USAF). The objective was to provide a means of training logistics decision makers to work with critical information and achieve the best use of resources. This tasking originated under a Memorandum of Agreement between HQ USAF/LGX, Air Force Systems Command (now the Air Force Materiel Command), and HR.

In response, HR let a contract to Systems Engineering Associates (SEA) to produce a desktop decision trainer which will provide individual instruction and enable students to practice solving realistic logistics problems in a Logistics Readiness Center environment. The project, which began in February 1992, will be completed in February 1997.

The objectives of the effort are to: (1) identify and develop instructional strategies for training decision-making skills; (2) identify and develop decision-making models to serve as a basis for training; and (3) develop an experimental computer-based training prototype that combines decision-making lessons with simulation environments to enable logistics personnel to experience the same kinds of problems and situations encountered in the operational environment. The prototype will enable them to practice their decision-making skills and obtain feedback on their performance.

I. INTRODUCTION

This report presents the development of an instructional strategy for training decision-making skills. It first describes the training problem to be solved, then presents the theoretical foundations for the solution. Next, the theoretical foundations are applied to the problem and a detailed training methodology for problem solving is developed. The training problem is described as a need to provide training for decision makers in Logistics Command and Control (LC^2), a need that is not adequately being met due to the lack of an affordable and effective methodology.

The theoretical foundations for solving the training problem were derived by addressing the following questions:

- What is decision making?
- How do people perform the decision-making task?
- How do people learn to perform the decision-making task?
- What can instructional design theories or models tell us about teaching the decision-making task?

The answers to these questions were applied to the specific requirement of training LC^2 decision makers. The result was a specification for a training methodology that will be implemented during the follow-on phases of the project.

The problem solution was developed in an eclectic fashion. No attempt was made to adopt and instantiate one particular theoretical framework. Rather, the intent was to bring the best thinking and empirical evidence to bear on the problem and to synthesize this knowledge into an internally logical and consistent conceptual framework. This framework would serve as an empirically verifiable foundation for the design and development of a training system.

II. PROBLEM

LC^2 and Tactical Command and Control (TC^2) units have a common training requirement: They both must ensure that core and augmentee personnel are fully trained in the critical combat skills of decision making in their respective domains. The commonality of training requirements has been documented by Schwaninger, Malin, and Gumienny (1991), who surveyed the training requirements for LC^2 personnel using methodologies pioneered by Brecke, Jacobs, and Krebs (1988). Schwaninger et al. (1991) found that the types of personnel and skills that need to be trained in LC^2 are the same as those identified for TC^2 in the earlier Brecke et al. (1988) study. Also common to both C^2 communities is the fact that the existing training capabilities are inadequate. They currently consist primarily of expensive and manpower-intensive exercises which afford only sporadic training opportunities that are insufficient to achieve and maintain the personnel skill levels required for successful combat operations. The need for more accessible, more affordable, and less manpower-intensive training, documented by both aforementioned studies, continues to exist.

The common shortfall in training capability indicates that both LC^2 and TC^2 units might benefit from the same training solution: a training technology based on desktop computers. This technology, which began to emerge during the early 1980's, uses the increasing power of desktop-based computer hardware and software technology to produce credible simulation environments within which the battle manager trainee can experience the same kinds of problem and decision-making situations encountered in the operational environment.

The feasibility of generating realistic tactical simulation environments for training on desktop-class hardware has been demonstrated with the SuperKEATS system developed by the Air Force Human Resources Laboratory (AFHRL) during an earlier effort (Brecke & Young, 1990). The SuperKEATS system achieves a realistic TC^2 simulation by means that are fairly simple compared with the complex means employed in large-scale simulation environments that are widely used to support exercises. While this is an encouraging result and a necessary first step in solving the training problem, it is not sufficient because it addresses only one side of the training methodology issue: the delivery strategy.

According to Reigeluth (1983), a complete specification of an instructional method requires the specification of three types of strategies: *organizational, delivery,* and *management*. An organizational strategy is a prescription for the organization of instructional macro and micro

elements. A delivery strategy defines the medium used to convey the instruction. In our case, the delivery strategy is given or prescribed and consists of computer-based self-instruction running on a desktop personal computer (PC) platform. A management strategy defines which organizational or delivery strategy components will be used under different conditions during instruction. Organizational and management strategies are not prescribed in our case; rather, they must both be developed and defined.

Organizational and management strategies (hereafter referred to as instructional strategies) cannot (yet) be taken off-the-shelf, even though an instructional strategy for decision-making skills was identified by Aagard and Braby (1976). This strategy has a great deal of appeal and face validity, but its empirical and analytical or theoretical support is unclear. The objective of this paper and of this project is to take a fresh look at the problem of training decision-making skills and to develop instructional strategies for this class of skills on the basis of current empirical and theoretical knowledge from the following four sources:

- A precise and complete definition of the type of task to be trained.
- A clear picture of the process of task performance.
- Explanations of the process of learning or skill acquisition for this type of task.
- Instructional design theories.

There are limits to what can be achieved from a "theoretical armchair." Even if these combined sources provide strong guidance towards a particular instructional strategy, it is impossible to guarantee that such a strategy is in any sense optimal. A careful derivation of instructional strategy from the sources listed above will certainly reduce the search space, but the optimal strategy for a given set of training conditions can ultimately be found only by empirical means. The training system produced by this project must also be capable of serving as a research testbed; therefore it must permit easy modification of the instructional strategies by which the system delivers training.

This report is devoted to narrowing the search space for the ideal or optimal instructional strategy for training decision-making skills. The goal is to define a recommended "strawman" strategy and to identify the elements of this strategy that require empirical validation and/or exploration. The report thus provides the theoretical underpinning for the design of a training system which, for research purposes, can be modified along a number of pre-specified dimensions.

III. THEORETICAL FOUNDATIONS

3.1. WHAT IS DECISION MAKING?

Definitions of decision making can be found in the literature (Anderson, Deane, Hammond, & McClelland, 1981; Janis & Mann, 1977; Nickerson & Feehrer, 1975; Webster 1981), but these definitions generally lack precision and completeness. To achieve a precise and complete definition for the class of decision-making tasks, a review of common definitions of decision making was performed. The review resulted in a three-component description of the decision-making process: (1) uncertainty model, (2) time line model, and (3) verbal definition. Together these components constitute a definition of decision making that is considered complete and precise enough for the purpose of developing a training methodology.

3.1.1. Uncertainty Model

The analysis of decision making began with an assessment of some common definitions found in the literature. Anderson et al. (1981) define decision making as "selecting and committing oneself to a course of action." This definition is clearly in consonance with the colloquial, popular understanding of the term, but it is also incomplete. Missing from this definition is an essential component that comes through in Webster's (1981) definition of the term: "1. to arrive at a solution that ends uncertainty." Taken together, the Anderson et al. and Webster definitions identify decision making as an activity that *ends uncertainty* through a *commitment* to a particular course of action. The notion of eliminating or reducing uncertainty and commitment appear to be essential aspects of decision making. Working from this foundation, focus was then placed on a more detailed analysis of uncertainty reduction. A primary goal was to relate the cognitive activity of uncertainty reduction to the affective activity of making a commitment.

Decision making begins with a perception that a situation has developed in which the following pertain:

- Significant action alternatives exist.
- There is pressure to commit to a course of action.
- There is an uncomfortable amount of uncertainty with respect to making that commitment.

All three of these conditions are required to trigger the decision-making activity. The action alternatives need not be well articulated or explicit, but there must be at least the implicit notion that more than one course of action is possible. In addition, there must be sufficient motivation or need to overcome a threshold of inertia and some degree of uncertainty.

This uncertainty is initially a basic dubiety about what to do, which course of action to choose, which alternative to commit to. This initial uncertainty is referred to as *primary uncertainty*. Primary uncertainty is reduced to zero as soon as the decision is made. In that sense, the Webster definition is exact: a decision is a solution that "ends" uncertainty. A decision determines which course of action is to be taken, or, if only one course of action is under consideration, it indicates that a commitment to "*the*" course of action has been made. This resolution relieves stress but does not reduce *all* uncertainty in the decision problem to zero (i.e., Webster's definition is only partially correct).

Three basic types of information are required for a decision. The absence of any one of the three results in an uncertainty that differs from primary uncertainty. This type of uncertainty is called *secondary uncertainty*. The decision maker *attempts* to reduce secondary uncertainty to zero *prior* to committing to a particular course of action. Three forms of secondary uncertainty have been identified in the literature (Coombs, Dawes, & Tversky, 1970; Einhorn & Hogarth, 1985; Kirschenbaum, 1986), but they have not been used together as components of a systematic definition of the uncertainty variable in decision making. The three types of secondary uncertainty are:

1. Situation Uncertainty (U_S).
2. Goal Uncertainty (U_G).
3. Option Uncertainty (U_O).

Situation uncertainty is uncertainty with regard to the situation that elicits the decision-making activity. Situation uncertainty is represented by questions such as, "What is going on?" or "What is the problem?" Decision makers' efforts to deal with this type of uncertainty have been referred to as "problem structuring" or "hypothesis formation" (Nickerson & Feehrer, 1975).

Goal uncertainty is uncertainty as to the goals or objectives that are to be achieved by the decision. Goal uncertainty is represented by questions such as, "What do I want to achieve?" or

"Why are we in this business?" or "What do I want to get out of this?" Goals or objectives may compete with one another, thus forcing the decision maker to prioritize them. This prioritization often requires an introspective or communal clarification process (or both).

Option uncertainty is uncertainty as to the options or action alternatives available to achieve the desired goals in the given situation. Option uncertainty is more complex than situation and goal uncertainty. Three distinct subtypes of option uncertainty can be identified:

1. **Set Completeness Uncertainty** (U_{OS}): Uncertainty as to whether the set of options under consideration is complete. This type of uncertainty is represented by questions such as, "Isn't there another way?" or "What else can we do?" or "Have I really considered all the possible alternatives?"

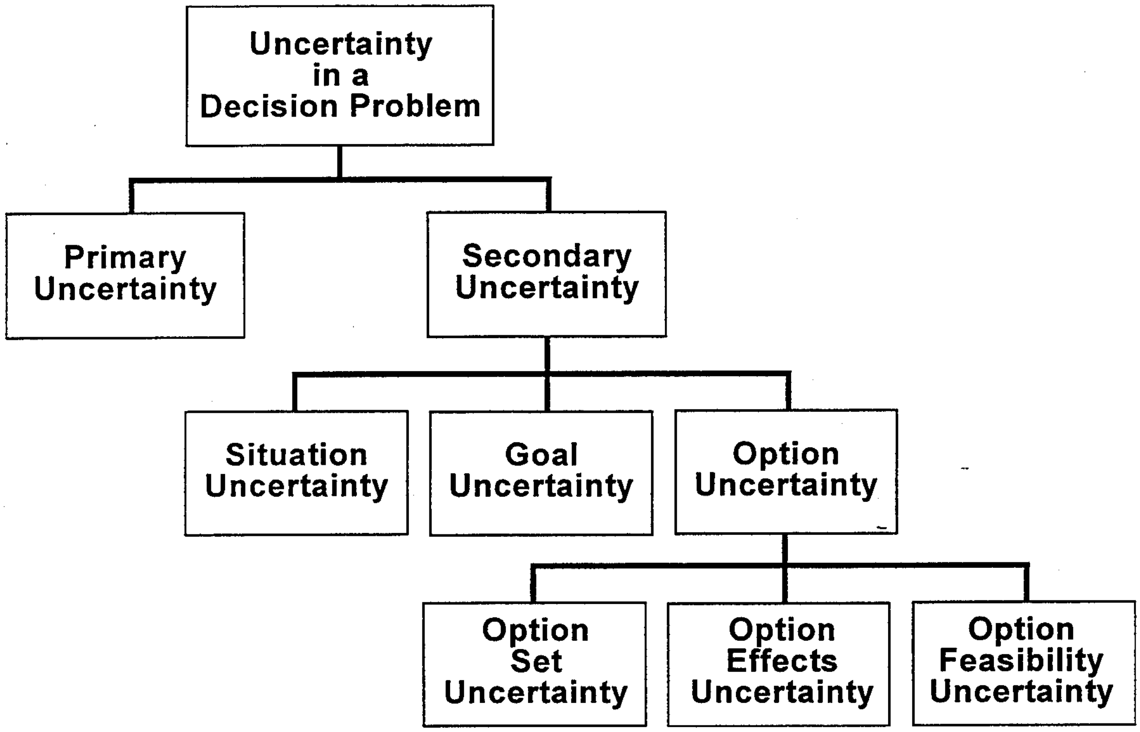
2. **Effects Uncertainty** (U_{OE}): Uncertainty about the effects or results of implementing a given option. When multiple options are available and/or considered, the decision maker may be very certain about the possible effects of some and completely uncertain about the effects of others. By the same token, there may be certainty about some effects of a particular option and much less certainty about other effects of the same option. Effects uncertainty is represented by questions such as, "What is this going to do for me?" or "Will the cure be worse than the disease?" or "Will this action have the desired results?"

3. **Feasibility Uncertainty** (U_{OF}): Uncertainty with respect to whether a given option can be implemented as desired. Feasibility uncertainty is represented by questions such as, "How old is this bungee cord?" or "Can I say it with a straight face?" or "What if the guard screams before I can cut his throat?"

Both primary and secondary uncertainty are usually present to some degree in any decision problem. The overall uncertainty in a decision problem is thus an aggregate of all the types of uncertainty that can be represented with the tree-like structure shown in Figure 1. This figure and its underlying notions are known as the "uncertainty model."

Prior to committing to a particular course of action, the decision maker *attempts* to reduce all these types of secondary uncertainty. The level to which the uncertainty must be reduced for the commitment to occur is basically a function of what is at stake for the decision maker, the available time and the costs of obtaining further information.

Figure 1. Uncertainty Model

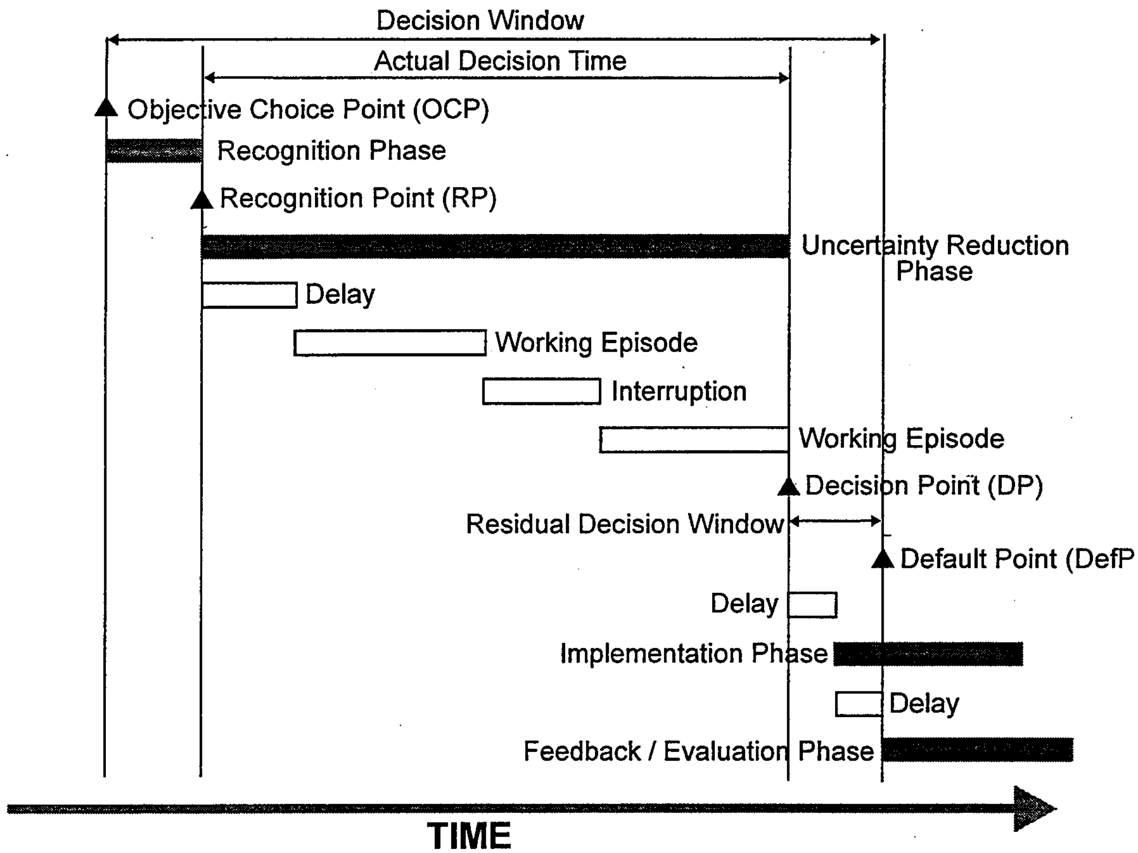


3.1.2. Time Line Model

Decision making is also a cognitive process that can be described in terms of a time line. This, strangely enough, has not been done before. The decision-making process has been decomposed into phases and/or sequences of tasks (Nickerson & Feehrer, 1975; Schrenk, 1969). But the main focus of these decompositions is usually on the nature of each phase rather than on temporal relationships, and the decompositions invariably carry a strong prescriptive (and therefore somewhat arbitrary) flavor rather than a strictly descriptive one.

The time line model pictured in Figure 2 reveals the temporal anatomy of the decision task. The time increments pictured could be anything from seconds to years. The diagram shows a "normal" (or perhaps "ideal") decision-making task. Many variations in the relationships between the phases and milestones are possible, each generating particular demands on the decision maker.

Figure 2. Time Line Model for Decision-Making Tasks



Most of the diagram is probably self-explanatory, however the following milestone labels require explanation:

Objective Choice Point (OCP): The OCP is the point at which the course of events surrounding the decision maker has produced a situation in which both the *opportunity* and the *need* for a decision are present. Prior to this point, a decision can be anticipated and can even be made in anticipation (as in a plan), but it need not be made and it cannot be implemented.

Recognition Point (RP): The RP is the point at which the prospective decision maker recognizes a need and an opportunity for a decision.

Decision Point (DP): The DP is the point at which the decision is made, the "moment of truth." More precisely, at this point the process of decision making proper has come to an end and the decision maker has *committed* to a particular option.

Default Point (DefP): The DefP is the point at which the need or opportunity (or both) for the decision disappears because it literally has been "overcome by events." This is where whatever will happen without interference by the decision maker will actually start to happen (i.e., the default course of events will occur). This may, of course, trigger another OCP, but that OCP will be the start of another, different decision evolution.

Figure 2 shows that the decision-making process begins with the OCP, which occurs when both the opportunity and the need for a decision appear in a given domain. The OCP may be preceded by an anticipatory planning or incubation period. The RP marks the point at which the prospective decision maker recognizes the opportunity and need for a decision and the start of the cognitive activities that are the heart of the decision-making process. These activities may either start immediately after recognition or after some delay, and they occur during one or more working episodes interrupted by work suspense periods. The last working episode ends with the DP. The DP should be reached before the DefP; implementation of the decision should also at least start before the DefP. There is a possible delay between the DP and the start of implementation. Feedback begins following the implementation (i.e., there is another possible delay) and can continue indefinitely after the implementation process has ceased. The end of the feedback process marks the end of the entire decision-making episode.

3.1.3. Definition and Discussion

The uncertainty model and the time line model can be combined into a verbal definition of decision making.

Decision Making Defined

1. Decision making is a cognitive *and affective* process that is triggered by the perception of the following:
   - The possibility of more than one course of action.
   - A certain amount of pressure to "do something."
   - A more or less complex aggregate of primary and secondary uncertainty.

2. The process begins with the OCP, ends with the feedback finish point, and incorporates four subprocesses:
   - Recognition.
   - Uncertainty Reduction.

- Implementation.
- Feedback.

3. Uncertainty reduction, bracketed by the RP and the DP, consists of activities designed to reduce all components of secondary uncertainty to levels where commitment to a particular course of action becomes possible.

4. Commitment to a particular course of action constitutes the decision. The decision reduces primary uncertainty to zero, while secondary uncertainty remains at the level it had when the commitment occurred (residual uncertainty).

5. Residual uncertainty can only be reduced further by feedback from the environment. Such feedback can only occur after the decision has been implemented, and it may be incomplete, difficult to interpret, delayed, and difficult to attribute to a particular decision. Feedback may even increase residual uncertainty as more information is obtained.

The act of choice or commitment in decision making *always* occurs in the face of residual secondary uncertainty. If it did not, there would have to be complete certainty of what the situation is, what the goals are, and which option optimizes the achievement of these goals; such certainty would not require a decision. In such a case, the problem is solved and the activities that lead to the solution can be called problem solving but not decision making. Since some secondary uncertainty remains, the act of choice and commitment requires more than ratiocination; it requires a push of affective energy to accomplish a daring leap into the unknown and *presently unknowable.*

This interpretation of the decision-making phenomenon essentially eliminates the distinction between risky and riskless decision making and between decision making under uncertainty and decision making under certainty. It asserts that decision making is *always* risky, *always* a gamble, and *always* occurs under uncertainty. Without risk and uncertainty, the process is simply one of "taking an action" rather than making a decision.

In addition to clarifying the distinction between choice and decision, this interpretation also clarifies the distinction between judgment and decision making. According to Fischoff (1989), judgment is needed to extract information from an uncertain environment, while decision making is needed to extract a course of action from those judgments in order to achieve some

goal(s). The information search that is undertaken to reduce secondary uncertainty must be supplemented by judgment to fill in the gaps between the morsels of "hard" information that are accessible to the decision maker.

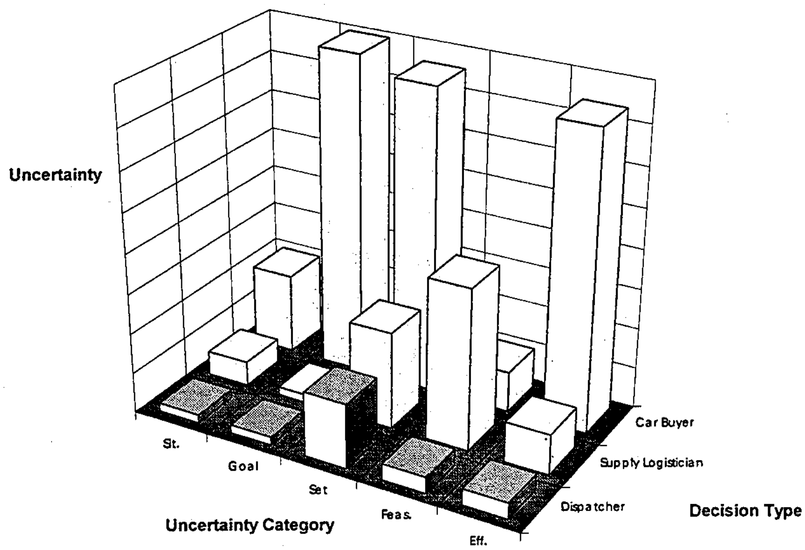
In this context, activities which produce a diagnosis, a situation assessment, or a prediction as their end result are often wrongly referred to as decision making. The aspect of uncertainty reduction is clearly present in such activities, but the other essential component of decision making, (i.e., the commitment to a course of action) is missing. For example, a doctor does not decide a diagnosis of cancer, rather a judgment is made based on symptoms. The doctor makes a decision only if this judgment is, explicitly or implicitly, tied to a commitment to a particular course of therapeutic intervention. An intelligence analyst who predicts a particular enemy route of approach does not decide on that approach -- the enemy does. A judgment is made based on a number of possible approaches that appear most likely. If the analyst is concerned about their personal credibility and standing with their commander, they may abandon their best objective judgment and commit to a particular prediction that they believe the commander "wants to hear." The analyst has indeed made a decision, but it is one regarding their own welfare, not one relating to possible enemy routes of approach.

Finally, it is clear that decision making is an activity with very strong affective components. The decision-making process is not initiated unless there is some motivational pressure, uncertainty reduction requires judgment that is subject to distortions caused by stress and other affective factors, and, finally, the process is not terminated unless there is sufficient affective impetus to overcome emotional barriers to commitment in the face of remaining uncertainty.

3.1.4. Models Applied to Examples

To illustrate the uncertainty and time line models, we apply them to three examples: decisions made by dispatchers in taxi companies, a decision a supply logistician may have to make during a conflict, and a car-buying decision made by a typical consumer. The examples are shown (in a side-by-side arrangement to permit convenient comparisons in Appendix A). Figure 3 presents a graphic image summarizing some points from Appendix A.

Figure 3. Graphic "Uncertainty Profiles" for Three Types of Decision-Making Tasks



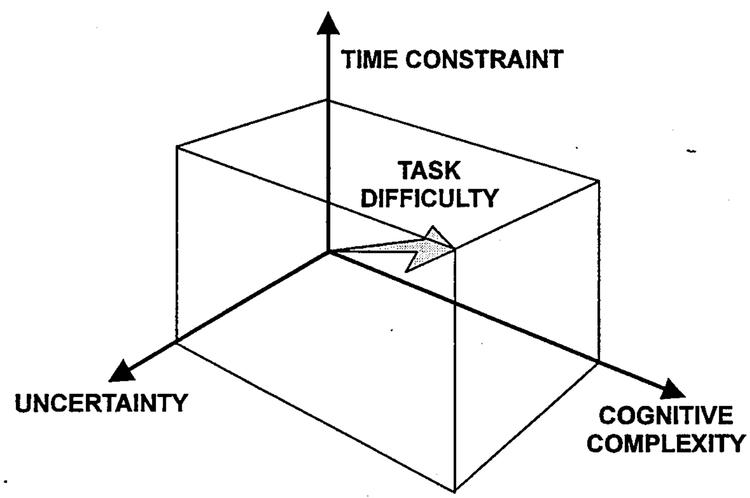
3.1.5. Taxonomic Issues

The models and the definition supplied above suggest taxonomic possibilities that are both practically useful and theoretically significant. For example, one might examine a type of decision task for which options must be developed and contrast it with another type of decision task for which the options are clear but the goals are not. The task type requiring option generation relies on creativity during task performance. Training such a task would require a training system capable of evaluating novel approaches to a class of decision problems, a capability not easily developed in a computer-based system. In the second task type, the decision maker has a clear set of options (i.e., certainty regarding the options, how feasible they are, and what the effects will be), but the goals are not firmly articulated and prioritized. This task type requires no creativity or originality and a training system would merely have to be able to recognize a correct choice from existing options. This capability is realized relatively easily in a computer-based training system. These two types of tasks obviously require fundamentally different cognitive activities to reduce secondary uncertainty; they also require different learning and instructional strategies during training.

Not only do the *qualitative* differences between uncertainty types have taxonomic value, the *quantitative* aspects of uncertainty also provide valuable dimensions of task discrimination. For example, a decision task that is normally easy to perform for personnel of a given

proficiency level can become a completely different task (i.e., a "Mission Impossible") when an information channel dries up (e.g., when a telephone line gets cut). In such a case, the amount of uncertainty suddenly rises substantially above normal levels. Both Howard (1968) and Brecke (1982) refer to the amount of uncertainty as an important dimension determining the nature of a decision-making task or of a judgment task. Both researchers see uncertainty as one of three dimensions that together determine the nature of a decision-making task. The other two dimensions are *complexity* and *time constraint* (see Figure 4).

Figure 4. Dimensions of the Decision Task



Additional key variables are *frequency of performance* and *task importance* (which is most likely some aggregate of personal and institutional variables). These types of variables are routinely used by training designers because they provide relevant criteria for training design decisions.

Some decision tasks are clearly very important, complex, and absolutely buried in uncertainties. However, if they occur only once or twice in a lifetime (such as deciding on a partner in matrimony), task-specific training may not have any beneficial effect (such as lowering the probability of divorce). On the other hand, some decision-making tasks, although they occur frequently, are so simple and trivial that any effort to provide formal training for them would be a waste of time. Between these extremes lie tasks that are the "bread and butter" of decision makers everywhere: tasks that occur frequently, represent a qualitatively and quantitatively significant portion of a given job performer's work, and are complex enough to

require nontrivial learning time and effort. Clearly, training developers and management should give such tasks priority. Furthermore, this line of reasoning facilitates intelligent allocation of training resources.

The uncertainty and time line models allow for development of descriptive and distinctive decision task profiles for real-world decision-making tasks (e.g. see Figure 3). These profiles can then be emulated by practice decision-making tasks presented during training. Therefore, the models are not only useful as theoretical taxonomic tools but also as instruments for ensuring that training tasks are structured like real-world tasks. The models can, in other words, make essential contributions to positive transfer of training. They can be used along with other factors to select tasks for training and, once selection has occurred, to ensure training effectiveness.

3.1.6. Training Considerations

The analysis of the decision-making process produced an arguably better understanding of the decision-making task. The question now is whether it is possible to draw some conclusions that contribute to an optimal training methodology for the task. Does this set of models and the definition help determine what the content of decision training should be or what the instructional strategy should or should not be?

If the models (and the definition) are enlightening and contribute to a better understanding of the task, it might be argued that students will benefit from knowing more about the general task (i.e., from instruction in this type of meta-content). They may further benefit from being able to recognize the specific forms of the time line model and the uncertainty model in the types of decision-making tasks that occur in the technical domain within which they will be called upon to make decisions.

Instructional Guideline No. 1

🗁 Include in the training system the capability to train students in the use of the uncertainty and time line models.

A more complete, precise, and detailed definition of the type of decision making provides clues for training content -- that is, WHAT should be taught. It also provides some important

clues regarding training strategy (i.e., regarding HOW this content and the associated skills should be taught).

Instructional Guideline No. 2

🗁 Ensure that practice problems have the same uncertainty and time line profiles as the target job tasks.

Guideline 3 is a corollary to guideline 2:

Instructional Guideline No. 3

🗁 Ensure that training provides for a practice environment that features the same types of information sources and requires the same kinds of information access procedures as the target environment.

Finally:

Instructional Guideline No. 4

🗁 During practice, gradually increase time constraint, complexity, and uncertainty to levels encountered in the target job environment.

3.2. How Do People Perform the Decision-Making Task?

3.2.1. Introduction

The answer to the question posed by the title of this section has been, and continues to be, the cardinal goal of descriptive research in decision-making. The ideal answer is a comprehensive *descriptive* model that accounts for the entire process of decision-making -- from the emergence of a decision problem (i.e., from the OCP) to the conclusion of the feedback process (i.e., the FFP). The ideal model also has to accommodate the view that the decision-making process is not a unitary phenomenon, rather it varies with the characteristics of the decision-making task as well as with the characteristics of the decision maker.

During the more than 40 years of rather vigorous research in decision making, such a model has been slow to emerge. Much of that time was dominated by a *prescriptive* rather than *descriptive* view of the decision-making process. This view was founded on the axiomatization of decision theory by von Neumann and Morgenstern (1947) and was manifested in a large number of studies. These studies compared human decision-making performance on contrived decision tasks in laboratory settings with logical or rational ideals of decision making expressed by mathematical models such as Bayes' theorem or Expected Utility theory. This research, although widely criticized for its dubitable generalizability to real-world decision making (for example, see Fischhoff, 1989), produced many valuable insights into the weaknesses and foibles of humans as decision makers. However, the preoccupation of this research paradigm with human suboptimality likely prevented an unbiased examination of actual, real-world decision making and the development of a complete descriptive model as defined above.

In the last five years, the pendulum has begun to swing more towards purely descriptive research. As a result, evidence is accumulating which indicates that in decision making, as in other cognitive tasks, experts go through a process that is qualitatively and quantitatively very different from the process novices go through. The process followed by experts appears to have little resemblance to the analytical models inspired by decision theory, whereas novices are forced to use such "weak" general logical methods. This more recent research has brought the heretofore rather elusive goal of a valid descriptive model much closer to reality.

The following paragraphs present the contributions of the earlier, prescriptively oriented research to an account of human performance in decision-making tasks. As more recent and purely descriptive research is discussed, the consistencies between these research findings with cognitive task models proposed by Clancey (1987) and Rasmussen (1988) are pointed out, and a process model based on the uncertainty and time line models presented in the preceding section is suggested. Finally, instructional design guidelines based on an understanding of the task performance process in decision making is provided.

The following discussion is limited to unaided decision making. This seems to be a particularly necessary clarification in the context of military decision making that has been the focus of vigorous research and development in decision *aiding*. Sheridan and Verplanck (1978) have distinguished 10 levels of allocation of decision tasks between humans and computers. At Level 1, the "human does the whole job up to the point of turning it over to the computer to implement." At Level 10, the "computer does the whole job if it decides it should be done, and if so, tells the human if it decides the human should be told." Of interest in this project is the

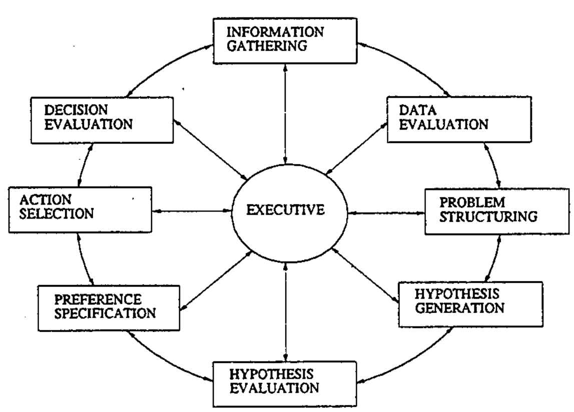
description of human decision-making performance at Level 1, where humans do it the "old-fashioned way."

3.2.2. Contributions of Earlier, Prescriptively Oriented Research

When Nickerson and Feehrer published a comprehensive review of the research in decision making in 1975, their intent was the same intent as that of this research effort: to derive prescriptive training principles. The authors concluded that despite the voluminous literature on decision-making research the number of studies that explicitly addressed the question of exactly what should be taught and how the teaching can best be accomplished is remarkably small. Therefore, they looked beyond such studies at a rather broad cross section of the general decision-making research literature. Nevertheless, the yield of prescriptive training principles was meager at best. The following paragraphs summarize the results of decision-making research up to 1975, relying heavily on Nickerson and Feehrer's landmark report.

Nickerson and Feehrer (1975) synthesized their findings in a model that conceptualized the decision-making process as consisting of eight subtasks, phases, or aspects and indicated clearly that this conceptualization has an element of arbitrariness about it -- as does any other. Their report is structured around these eight aspects and presents for each what was known about it at that time and the training guidelines one might derive from that knowledge. This model is provided in graphic form in Figure 5. This figure shows a central "executive" aspect or function that seems to be implied, but is not explicitly identified, by Nickerson and Feehrer.

Figure 5. Nickerson and Feehrer's Descriptive Model of Decision Making



Rather than paraphrasing Nickerson and Feehrer's discussions of each aspect in an abbreviated form, the essential conclusions are provided in Table 1. Nickerson and Feehrer's report demonstrates that, at the time the report was prepared, the decision-making knowledge base was not complete enough for researchers to derive from it any sort of coherent set of prescriptions for training. In a more recent review, Boff and Lincoln (1988) compiled a table of human decision-making characteristics that presents findings similar to those of the Nickerson and Feehrer report. Their findings are provided in Table 2.

Table 1. Findings in Nickerson and Feehrer (1975)

ASPECT	DECISION MAKER BEHAVIOR & CHARACTERISTICS	TRAINING GUIDELINES
INFORMATION GATHERING (= acquiring information to reduce uncertainty)	• Limited capacity to assimilate information • Purchases too much information when uncertainty is low and vice versa • Consults unreliable sources too frequently and vice versa	• Train to recognize limitations to assimilate information
DATA EVALUATION (= judging the "quality" of data)	• Evaluates reliability and validity of data informally, not in quantitative terms • Very low levels of inter-subject agreement	• Establish formal mapping between verbal terms and numeric terms • Train that mapping
PROBLEM STRUCTURING (= make the structure of the problem explicit)	• Typical approach appears to be from general to specific • Little known aspect of decision making	• Provide model structures for specific domains • Train people to solve problems in different ways • Train the general-to-specific approach
HYPOTHESIS GENERATION (= generate hypotheses on a situation)	• Generally quite adept at generating hypotheses • Intelligently and flexibly adapts hypothesis formulation strategy to situational constraints • Has a tendency to persevere with a disconfirmed hypothesis	• Train to avoid perseverance • Promote creative thinking
HYPOTHESIS EVALUATION (= judging probability of the truth of a hypothesis)	• Prone to logical fallacies • Pretty good at estimating relative frequencies, means, and medians • Representativeness heuristic: similarity is an index of class membership • Availability heuristic: ease of remembering instances is an indication of frequency of occurrence • Conservatism: extracts less information from data than the data contain • Partiality: gives more credence to evidence that confirms a favored hypothesis than to evidence that disconfirms it	• Train decision makers to be aware of the heuristics and to guard against their misapplication • Train to avoid conservatism and partiality • Train in the concepts of Bayesian theory • Train to estimate posterior probabilities
PREFERENCE SPECIFICATION (= specifying which of several outcomes is preferred)	• Capable of "holistic," multidimensional evaluations • Number of dimensions that can be handled successfully is limited • Random error increases with number of dimensions considered • Has a tendency to rationalize (to make up the numbers a posteriori to fit an implicitly made decision)	• Train people to make judgments independent of the worths of decision outcomes • Train people to make judgments independent of worth measuring technique • Train in decomposition and aggregation methods • Train people to make explicit and prioritize (weigh) worth factors
ACTION SELECTION (= the decision point)	• Must often occur under high residual uncertainty • Selections made when in a position of disadvantage considerably worse than selections made in a position of advantage	• Train under conditions of disadvantage
DECISION EVALUATION (= evaluating decision "quality")	• Not treated as a process performed by the decision maker	

Table 2. Human Decision-Making Characteristics of Boff and Lincoln (1988)

Type of Decision-Making Task	Characteristic Decision-Making Behavior	Source
Estimates of Descriptive Statistics	• Good at estimating means • Good at estimating proportions but shows some tendency to underestimate high proportions and overestimate low proportions • Poor at estimating sample variance; usually underestimates it	Peterson & Beach (1967) Peterson & Beach (1967) Peterson & Beach (1967), Sage (1981), Schrenk (1969)
Statistical Inferences from Samples	• Very conservative in making probability estimates, probably due to misunderstanding of sampling distributions • Believes small samples to be more typical of populations than is warranted	Peterson & Beach (1967) Peterson & Beach (1967)
Understanding and Use of Probability Statistics	• Good at understanding and using probability statements not based on frequency (e.g., "The probability of rain today is 0.7") • Tends to overestimate probability of favorable outcomes and underestimate probability of unfavorable outcomes	Peterson & Beach (1967), Sage (1981) Sage (1981)
Problem Change Recognition	• Too conservative in recognizing changes in problem conditions • Delays too long in response to those changes	Schrenk (1969), Vaughan & Mavor (1972)
Situation Diagnosis	• Poor at making diagnosis of complex situations entailing complicated interpretations of configural cue patterns	Hopf-Weichel et al. (1979), Vaughan & Mavor (1972)
Formulation and Selection of Action Alternatives	• Not sufficiently inventive and tends to adopt the first solution developed • Forms hypotheses early, then tries to confirm rather than test them • Does not consider enough hypotheses	Hopf-Weichel et al. (1979), Vaughan & Mavor (1972) Schrenk (1969)
Identification and Use of Decision Criteria	• Finds it difficult to use more than one or two criteria at a time • Tends to identify only those criteria favorable to selected action	Hopf-Weichel et al. (1979), Vaughan & Mavor (1972)
Use of Available Information	• Tends to use only concrete, high-confidence facts and prefers to ignore ambiguous or partial data • Asks for more data from sources of good quality information • Requests more evidence than is necessary for a decision • Poor at combining evidence to update probability estimates • Gives undue weight to early events and is reluctant to change an erroneous commitment in light of new evidence	Hopf-Weichel, et al. (1979), Vaughan & Mavor (1972) Schrenk (1969), Vaughan & Mavor (1972) Schrenk (1969) Schrenk (1969) Dale (1968), Schrenk (1969)
Detection of Change in Statistical Properties of Monitored Processes	• Exhibits near optimal behavior in optimal estimation and optimal control experiments, even though sophisticated interpretation of dynamic probabilities is involved	

The overall conclusion from this table is that "as statistical decision makers, humans are generally inefficient at making estimates of either descriptive or inferential statistics. Conversely, humans are effective decision makers when they have had input into the situations they are monitoring, and when they are highly practiced" (Boff & Lincoln, 1988).

Several observations can be made at this point:

1. The two tables complement each other and present a somewhat fragmentary picture of the human decision maker as a basically suboptimal (perhaps in rare cases near-

optimal) performer of aspects or subtasks in decision making. Whether one accepts that picture depends on whether one believes the methodological threats to generalizability of laboratory results to real-world situations must be taken seriously.

2. Whether these subtasks are performed is a function of the nature of the specific decision-making task, but there is not a systematic classification of decision-making tasks based on performance requirements.

3. The subtasks of decision making (see the first column of either table) address the uncertainty reduction process that occurs between the recognition point and the decision point. They do not provide any insight into the preceding recognition process nor into the succeeding implementation and feedback processes.

4. The various subtasks are to some extent arbitrary conjectures based on process models that arise from logical considerations of what decision makers *ought to be doing* rather than from *in-situ* observations of real-world decision making that would have revealed what they *are actually doing*.

The prescriptive focus can be explained as the legacy of decision theory that has so dominated the thinking about the decision-making process that an unbiased descriptive view was essentially prevented for decades. This is not to say that prescriptively oriented research did not produce or is not producing valuable results. The knowledge represented by Tables 2 and 3 is necessary; it is simply not sufficient. If those tables represented all the knowledge available for developing guidelines for training design, training would be matter of teaching prospective decision makers what *not* to do rather than what they *should* do. Fortunately, this is not the case.

3.2.3. Contributions of Recent Research

Between 1985 and 1988, Klein and Calderwood (1990) explored decision making in *operational* settings using a combination of **field studies** and experiments to test specific hypotheses. The decision domains included in this research were those of urban fire ground commanders, wildland fire incident commanders, and U.S. Army tank platoon commanders. Their most important findings, which were in many cases at odds with the traditional, prescriptively biased concept of the decision-making process, added considerable depth to a purely descriptive view of decision making. These findings are as follows.

- Experienced decision makers rely more on situation assessment, while novices rely more on option evaluation strategies.

- Situation assessment seems to involve schematic or prototypical knowledge of cues, goals, and expectancies that apply to a given class of events. Current cognitive research paradigms have not addressed how complex decision events are classified.

- Although experts and novices notice the same cues in a situation, novices draw fewer inferences based on these cues. Novices tend to miss the tactical implications of situational cues.

- At least in the domains studied here, decisions are most likely to be made without any conscious deliberation between option alternatives.

- When deliberation occurs, decision makers are more likely to use serial evaluation strategies than concurrent evaluation of options. Serial strategies offer a means of minimizing the calculational burden, and maximizing the speed with which a decision can be implemented.

- Serial evaluation is associated with satisfying rather than optimizing strategies and is preferred under time-pressured conditions.

- Options are frequently evaluated through the use of images or a "mental model" that operates as a simulation for judging whether an option will be successful in a specific case.

- Expert decision makers rely on a process of "progressive deepening" or reasoning into the future.

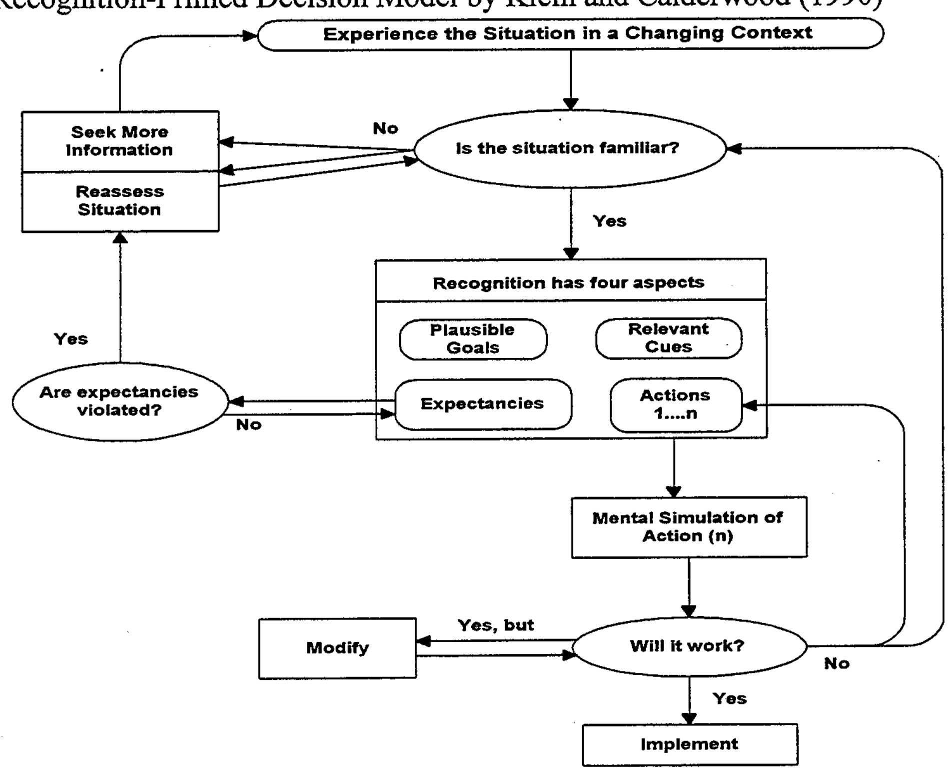
- Analogical reasoning is infrequently reported, which suggests that the processes involved in selecting and using analogs are relatively automatic and unconscious.

- When analogs are used (often to address aspects of a problem that are not routine), they are critical to option selection. Thus, inappropriate analogs are a primary cause of errors.

- Time pressure does not affect the quality of decisions made by experts as much as it affects novices because experts rely more heavily on rapid recognitional processes.

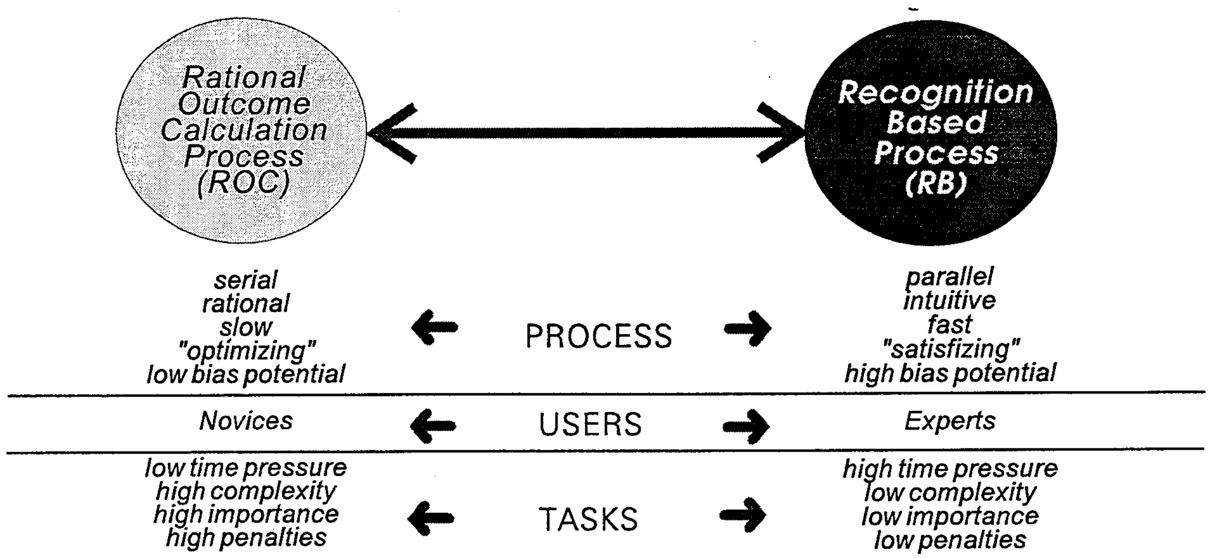
Klein and Calderwood (1990) have synthesized their findings in their Recognition-Primed Decision (RPD) model (Figure 6).

Figure 6. Recognition-Primed Decision Model by Klein and Calderwood (1990)



During the same time frame, Noble and his associates (Noble, Grosz, & Boehm-Davis, 1987) conducted a series of studies to examine the development and use of schemata in decision making. Starting with a general model of decision making proposed by Lawson (1987), they distinguish two modes of decision making: Rational Outcome Calculation (ROC) and Recognition-Based Decision Making (RB). The former is defined as a "rational process of explicitly comparing options and choosing the optimal alternative," while the latter is a mode where "the decision seems to follow directly from a recognition of the type of situation and a recollection of what actions usually work well in this kind of situation." Noble and his associates see these two modes as the two extremes of a continuum of decision-making strategies, where the space between these poles is occupied by what they call "hybrid" strategies. This concept is illustrated in Figure 7.

Figure 7. Continuum of Decision-Making Process Types



The relationship between Klein's Recognition Primed Decision Making and Noble et al.'s Recognition Based Decision making is obvious. Hammond (1986) essentially makes the same distinction when he refers to "analytic" versus "intuitive" modes of decision making. A similar distinction is also made by Rasmussen (1988) who differentiates between rational, knowledge-based decision making and heuristic, rule-based decision making and indicates that the former process is used by novices (and by experts facing unfamiliar situations) and that the latter is "applied by skilled actors."

Particularly interesting for the purposes of this paper is the Noble et al.'s (1987) account of what influences the use of one or the other strategy:

> Three factors influence the relative role played by recognition versus outcome calculation in a decision. These are knowledge or familiarity with decision. The more familiar a person is with a situation, the larger the role subconscious classification will play in his decision making. Difficulty in projecting outcomes caused by time or resource limitations or by a large number of situation uncertainties encourages a person to rely more on the classification process. Finally, the less important it is that the person make the very best decision, the more likely the person is to rely on subconscious classification. (p.7)

Noble et al. later state:

> The extent to which these two elements arise in any decision will depend on the characteristics of the task, the familiarity of the decision maker with the task, the severity of consequences for bad decisions, and preferred decision modes specific to the individual decision maker. (p. 9)

Noble et al. (1987) concluded that schemata are the foundation for expert decision making. Although they cannot offer any insight into how such schemata are developed, they are assumed to be a product of experience. The schemata allow decision makers to identify high quality alternatives directly from the situation. Further, they are organized around prototypes and contain feature data that enable people to evaluate the significance of differences between an observed situation and the typical prototype situation.

The results obtained by Klein et al. (1990) and Noble et al. (1987) are consistent with each other and with the findings of much of the research dealing with the nature of expertise and the differences between novices and experts. The picture of the human decision-making process that arises from the combined results of this research can be summarized as follows.

1. There are two distinct pure forms of the decision-making process that rest at opposite ends of a continuum populated by mixed or "hybrid" processes. One pure form is the ROC process, which involves conscious, analytical, knowledge-based processing within an overall logical, systematic framework. The other pure form is the RB process, which involves unconscious, intuitive, heuristic-based processing.

2. How much either process is used on a given occasion is a function of decision task characteristics and decision maker characteristics. Keeping task characteristics constant, novice decision makers will operate closer to the ROC end of the continuum and experts will operate closer to the RB end of the continuum. Keeping experience constant, decreasing time pressure and increasing task complexity, increasing task risk (consequences of bad decisions), and increasing uncertainty will increase the use of ROC processes over RB processes and vice versa.

3. The ROC process is a weak, general, rational problem-solving procedure that is probably minimally adapted to the gross features of the decision-making domain and is to some extent modified by prior experience in *related* or *similar* domains. The initial concern is reduction of situation uncertainty which, in Nickerson and Feehrer's (1975) terms, probably involves processes of information gathering, data evaluation, problem structuring, hypothesis generation, and hypothesis testing. The second concern is the reduction of uncertainty regarding goals to be achieved by the decision. This probably involves explicit clarification of personal goals, consultation of external "public" sources of guidance, or both. The third and really central concern is the reduction of uncertainty concerning options. This reduction will involve generation of the option set, assessment of the possible option effects in view of the goals to be achieved, and finally an assessment of the feasibility of each option. The ROC process will generally be performed with the intent of achieving a decision that is logically consistent with the available information and optimal as far as goal achievement and feasibility is concerned.

4. The RB process is characterized by rapid or near instantaneous and not necessarily conscious aggregation of situational data into a situational assessment. The situation is identified as a member of a problem class that is defined by a prototype (which is probably a schema). Simultaneous with situation recognition, the prototypical solution (which is also probably a schema) appears for members of this situation class. Deviations of the actual situation from the prototype situation are recognized and provide cues for adapting the prototypical solution to the current actual situation. In general, experts first are concerned with the reduction of situation uncertainty. This initial problem solved, they "see" the problem and a fairly specific solution for it at the same time, then spend the remainder of the available decision time primarily reducing uncertainty associated with the feasibility of the one option they are considering. The primary mechanism for reducing this type of uncertainty appears to

be something like imagery-based simulation using some sort of "runnable" mental model. Uncertainty concerning goals to be achieved by the decision commonly does not appear to be a concern; that is, experts are familiar with the general goals of their job and "know" what goals can or cannot be achieved in a specific situation. The RB process is generally performed with the intent of satisfying goals and requirements rather than optimizing their achievement.

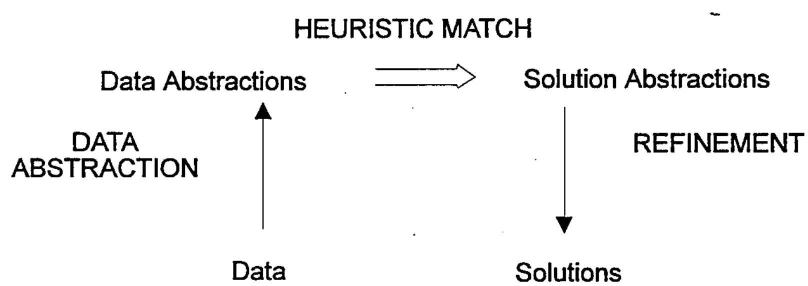
This is certainly a richer, more comprehensive, and more realistic view of the decision-making process than that produced by the earlier, prescriptively contaminated research; howeaver it is not so much an alternative view as it is a complementary one. The concept of option assessment and choice, which was central to earlier views of decision making, is confirmed as a feature of the process engaged in by novices. It is also central when the task is very important and when there is ample time to perform it. But when experts are performing under time pressure, its centrality evaporates and gives way to concerns of situation recognition and feasibility assessment. The biases and weaknesses of humans as statisticians and probability estimators are probably afflictions that have their greatest effect when decision making proceeds along the lines of the ROC process; it is in this process that knowledge of biases and weaknesses might be usefully brought to bear. On the other hand, rigidity, lack of creativity in problem structuring, and perhaps perseverance are probably dangers that experts should guard against. Their ingrained schemata could prove dysfunctional in situations that are superficially close to typical situations.

Although this is a richer and more comprehensive description, the process is still not described in its entirety. Several issues have not been addressed yet, such as how a decision maker recognizes the need for a decision in the first place and with what factors influence the duration and reliability of the recognition process. There also has been little concern with the "aftermath" -- the processes that occur after the decision is made (after the DP). For example, very little is known about how the "embedded" decision on when to start implementation is influenced by task or skill factors, how feedback is used during or after implementation, what constitutes useful feedback, and how feedback is employed in decision chains as opposed to singular, independent decisions. However, the crucial mid-phase, which encompasses what is more narrowly understood as decision making, has become much better understood.

3.2.4. Process Models

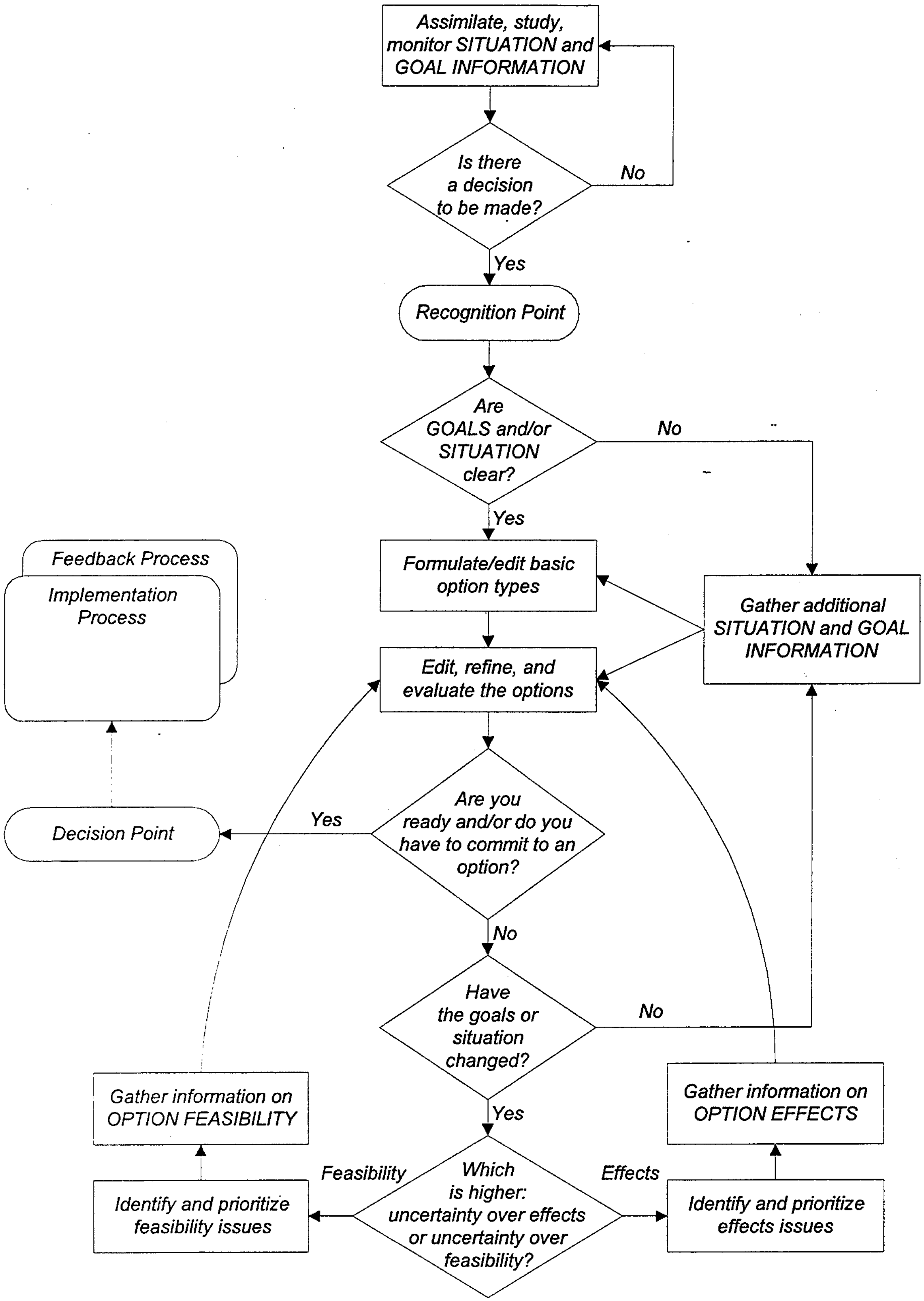
One simple and illuminating way to model the mid-phase is offered by the inference structure of heuristic classification in Clancey (1985) (Figure 8). The data abstractions are, in fact, situation classes represented by prototype schemata. The solution abstractions are option classes represented by schemata of prototypical solutions. Situation and option classes are linked by a heuristic match. The option classes are further refined into specific options. Both experts and novices traverse this arc of an inference structure from bottom left to bottom right, with novices slogging through it laboriously, analytical step by analytical step, while the experts see the entire pattern in one fell swoop, perhaps dimly in places at first but with increasing clarity as they probe here and there for missing or confirming elements of information.

Figure 8. Clancey's (1985) Inference Structure of Heuristic Classification



There are striking parallels between Clancey's (1985) model and a model of the decision-making process developed by Rasmussen (1988). There, too, a set of concrete initial data leads to the identification of a situation class that is linked to a desired goal state which is then refined into an executable, concrete solution. Last, but not least, we suggest a process model of decision making that is based on the uncertainty and time line models presented in the preceding section. The process model focuses on the uncertainty reduction process and covers the cognitive activities between the RP and DP. This model (Figure 9) is not *descriptive*. At best, it is a descriptive hypothesis: Given the logical relationships between types of uncertainty, this is the sequence decision makers can be expected to follow. Whether they actually do it this way has not been shown empirically. One may also hypothesize that the model is a useful prescriptive "job aid" for decision making. Whether that is true will be one issue that can be tested empirically with the system to be developed under this project.

Figure 9. Process Model for Decision Making

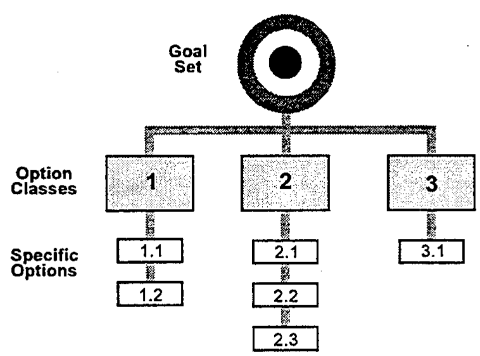


The two key notions embedded in this model are (1) the notion of logical order of precedence in uncertainty reduction and (2) the notion that goals, option classes, and specific options form a means-ends tree. Logically, uncertainty reduction should follow the order Situation - Goals - Options: One cannot make much headway with either goals or options until the situation has been clarified, and one cannot weigh options until the goals have been clarified.

A particularly interesting issue is the question of what happens in the box labeled "Edit, refine and evaluate the options." The prescriptive view as expressed by the multi-attribute theory, Bayesian statistics, or Fogel's (1992) valuated state space is not representative of what decision makers actually do. On the other hand, a validated descriptive view for the set of cognitive activities lumped together in this box does not yet exist.

It is *surmised* that decision makers construct the kind of relatively simple means-ends trees shown in Figure 10 with a goal set on top, option classes in the middle, and specific options at the bottom. It is also surmised that tree construction and editing is a fluid process, where perhaps only the goal set is relatively stable, and option classes and specific options are added, subtracted, refined, and evaluated as new information becomes available (i.e., as the decision maker progresses in efforts to reduce uncertainty).

Figure 10. Means-Ends Tree Concept

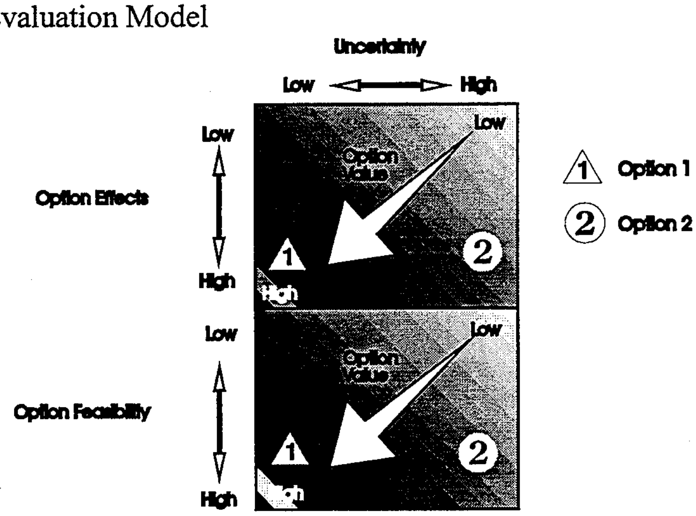


This tree-building and editing activity probably changes considerably as expertise increases. Novices can only develop a few options or at most a rather sparse tree because they simply do not know enough to do more. As domain knowledge and experience increases, the tree is likely to become larger and more complete up to a point, then the tree begins to "shrink" again. The expert has a very sparse tree where a goal set, an option class, and a single option form one clear, coherent path.

This view provides one possible explanation for the differences between novice and expert performance: The expert has seen the tree before and can very quickly prune it down to the most promising option class and specific option, whereas the novice must develop and assess the entire tree branch by branch. This leads to a preoccupation with option generation by novices who use the ROC process and to a preoccupation with feasibility of specific options by experts who are running the RB-type of process.

As decision makers work on reducing various categories of uncertainty, they acquire new information that allows them to prune or expand the tree, edit option classes and options, and evaluate and compare options. The latter activity is necessarily concerned with option effects and option feasibility. Options that have a high potential to satisfy the goal set and a high potential of being feasible are of course more valuable than options that have low effects and feasibility potentials. But evaluation must also be concerned with uncertainty, as illustrated in Figure 11. An option with a high but very uncertain effects potential (Option 2) is less valuable than an option with equally high effects potential but less effects uncertainty (Option 1); of course, the same is true for the feasibility variable. Figure 11 represents a simple option evaluation model that has the potential of being descriptive because of its relative simplicity.

Figure 11. Simple Option Evaluation Model



3.2.5. Training Considerations

Three major points can be derived from the preceding discussion. The first is the notion of human deficiencies in decision making. Research in this area continues to be actively pursued today. For example, Tolcott, Marvin, and Lehner (1989) are investigating bias phenomena in the treatment of confirming versus disconfirming evidence. This is also the area where Nickerson

and Feehrer's 1975 report provides its most explicit and insightful training guidance. Their thoughts on that subject and its training implications are still valid today and can be summarized as follow.

- There are two types of human deficiencies; Nickerson and Feehrer label these "deficiencies" and "limitations." Deficiencies, such as the tendency to be overly conservative in the use of probabilistic information, can presumably be corrected or "trained out." Limitations, such as "the inability of most people to weigh more than some small number of factors" cannot be corrected; they can only be "trained around" or helped by job aids.

- If experimental research can reliably identify some fairly universal deficiencies (and, given the methodological problems of such research this is a big if indeed), one would obviously want to correct these deficiencies during training. Nickerson and Feehrer suggest exposing students to a wide variety of decision-making situations in which a particular deficiency is likely to appear, then providing immediate feedback to the students on the appropriateness of their behavior.

- With regard to limitations, Nickerson and Feehrer suggest that "the goal should be to educate the decision maker concerning what those limitations are and to provide him with the means for working around them." In other words, these authors suggest a combination of consciousness raising and job aiding.

The researchers involved in this current effort concur with these suggestions and advocate an approach that begins with a careful selection of a few deficiencies and limitations. Prime candidates are those that are both reliably identified by a variety of research paradigms *and* likely to have highly adverse effects on decision-making results. The selected deficiencies should then be "trained out" through explanation, exposure, and feedback. The selected limitations should be "trained around" through explanation and by providing methods or procedures that assist learners in coping with information processing demands for which they are ill-equipped. These recommendations are summarized in the following two guidelines:

Instructional Design Guideline No. 5

🗁 Train students how to avoid and/or overcome deficiencies by using practice situations in which deficiencies are likely to show up.

Instructional Design Guideline No. 6

🗁 Train students to cope with limitations by including explanations, procedural aids, and appropriate practice and feedback in situations where limitations are likely to manifest themselves.

The second major point derived from the discussion of process models is that novices and experts engage in qualitatively and quantitatively different processes or modes during decision making. How, then, might one optimally promote the development of an RB mode through training? One obvious strategy is to provide ample amounts of practice in realistic and increasingly complex decision-making situations. However, there is the potential to do more. Because the ROC and RB modes are vastly different, instructional treatments that are optimal for a novice engaging in ROC decision making are not necessarily optimal at higher levels of proficiency where the learner begins to abandon the ROC mode and to engage in the RB type of decision making (i.e., instructional treatments are likely to be more effective if they are adapted to the learner's level of proficiency). For example, a learner at the early ROC stage might benefit from being held to a systematic, rational, and explicit approach. As the learner's proficiency increases, explicit cues and procedures can be abbreviated and/or replaced by "compiled" or condensed cues. Finally, such cues can be eliminated completely. This notion of adapting the instructional treatment to learner proficiency is explored further in the next section, where the focus is on the learning process for decision-making skills. At this point, we suggest the following guidelines:

Instructional Design Guideline No. 7

🗁 Provide high levels of increasingly complex practice in realistic decision-making situations.

Instructional Design Guideline No. 8

🗁 Adapt instructional treatments to learner proficiency by gradually compiling and finally withdrawing instructional cues.

The third and final significant point is the notion of a general or universal method for decision making that goes along with the uncertainty and the time line models developed in Section 3.1. This model, while logically valid, has not yet been proven as a valid description of

either ROC or RB modes in decision making. However, it might be a valid description of either mode, and it might function as a useful methodological prescription for decision makers at any level of proficiency. Whether this is right is an issue for empirical research. Since this project aims to produce a training system that can be used for research, the following guideline is offered:

> **Instructional Design Guideline No. 9**
> 🗁 Include in the training system the capability to train students in using the process model for decision making.

3.3. How Do People Learn Decision Making?

3.3.1. Introduction

How do people learn the decision-making process? The ideal answer, again, is a comprehensive descriptive model that accounts for the entire learning process from the state represented by novices in a particular domain to the state represented by domain experts. The volume of existing theoretical and empirical research that could be brought to bear on that issue is exceedingly large. A comprehensive and thorough review of this body of literature is simply impossible under the constraints of this project, even if the focus of the review is restricted to the subset of research that deals with the acquisition of complex cognitive skills. Therefore the focus has been narrowed and restricted to a number of independently developed, multistage skill-acquisition theories. The notion of multiple stages in the learning process is interesting from the viewpoint of instructional design because the existence of stages might allow precise tailoring of instructional treatments to each stage, which in turn might lead to faster, more efficient learning. This notion was introduced in the preceding section where the focus was on decision-making performance; here, this notion will be expanded further.

The literature on novice-expert differences gives an idea of the territory that must be traversed during the learning process. If there are indeed identifiable stages in the process, they can serve as guideposts for the journey through what otherwise is "terra incognita." However, in negotiating these stages, one will likely find that a singular type of instructional treatment cannot be effective and/or efficient *throughout* the entire process. Consequently, the instructional treatment must, in some fashion, *adapt* to the changes that occur in the learner in order to achieve optimal promotion of the learning process. That adaptation would have to take its cues from

identifiable changes in learner behavior. For example, a multistage skill acquisition theory can achieve practical significance for instructional design if it can demonstrate *empirically* that the stages are *clearly and easily* detectable *and* if it offers insights that can be translated into instructional design prescriptions that, when correctly implemented, will promote transition from one stage to the next.

3.3.2. Multistage Skill Acquisition Models

A number of multistage theories were examined in the course of this project. The common themes running through these theories led to the development of a Unified Model for Skill Acquisition (UMSA) -- a *synthesis* of several multistage skill acquisition theories. The theories examined for the UMSA and the stages proposed by each theory are presented in Table 3. These theories describe stages in terms of changes along a number of dimensions. Commonalities were found, both in the dimensions that were used and in the changes that were described for these dimensions. In other words, the commonalities went beyond the common theme of a gradual process marked by stages. It was therefore believed that one could, without excessive distortions, fuse the essential themes in each theory into one common, unified model that would come closer to descriptive truth than did each constituent models alone. The result was the UMSA (Table 4) in a form slightly abbreviated from the original.

Table 3. Multistage Skill Acquisition Theories and Their Stages

Theories	Stages				
Dreyfus & Dreyfus (1980)	Novice	Advanced	Competent	Proficient	Expert
Siegler (1978)	Rule I Behavior	Rule II Behavior		Rule III Behavior	Rule IV Behavior
Gentner (1980); Forbus & Gentner (1986)	Protohistories	Causal Corpus		Naive Physics	Expert Models
McDermott & Larkin (1978)	Verbal		Naive	Scientific	Mathematical
Anderson (1982)	Cognitive		Compilation		Procedural
Fitts & Posner (1967)	Cognitive		Associative		Autonomous
Rasmussen (1986)	Knowledge-Based		Rule-Based		Skill-Based

Table 4. Unified Model for Skill Acquisition (UMSA)

	Level 1 Stage 1 Novice	Level 1 Stage 2 Experienced Novice	Level 2 Stage 3 Capable Learner	Level 2 Stage 4 Proficient Learner	Level 3 Stage 5 Skilled Learner	Level 3 Stage 6 Expert
Type of Knowledge	Declarative	Declarative	Declarative with simple procedures in step-by-step format	Integrated rules (2 to 3 rules)	Procedural	Procedural
Type of Learning	Verbal information	Verbal information; discrimination learning with simple concrete concepts	Concrete concept learning; some very general problem-solving strategies	Abstract concept learning; some domain-specific problem-solving strategies	High-order rule-learning, complex problem-solving, cognitive strategies learning	High-order rule learning, complex problem solving, more general cognitive strategies applied
Cognitive Processes	Memorizing facts and rules; rehearsing information for recall	Comprehending facts and rules relative to context	Classifying based on concrete features; simple links between declarative knowledge & procedures; simple hypotheses for problem solution; some meta-cognitive processing	Forming higher order rules by combining rules; forming principle-based relalational links in networks; testing alternative hypotheses; meta-cognitive monitoring of learning & effectiveness	Formulating high-level productions; elaborative inferencing to delimit possible solution paths; active and effective meta-cognitive processing	Refining representations and associated productions; testing productions for efficiency & comprehensiveness; active and effective meta-cognitive processing
Knowledge Organization	Listings of facts and rules; unrelated knowledge forms	Simple structures linked by a few surface features	More complex and meaningful structures; complete linking of surface features	Modified representations with principles included, some procedural relationships	More abstract representations including principles and procedures; productions for executing knowledge structures	Highly integrated systems of concepts, principles, productions, and macro-productions
Role of Context	Context-free; defined rules detached from total context	Some context-specific features with context-free rules	Increased focus on context composition & similarity with situations from same domain	More attention to processes & principles underlying context & their generalization to other settings	Context features are related to other domains; context rules are inferred from varied settings	Context-specific rules are abstracted into generalized productions; automated systems of context-free and context-specific rules for particular problem types
Processing Characteristics	Very slow; very resource demanding	Very slow, effortful	Improved efficiency in retrieval of declarative knowledge but still slow and effortful	Improved processing of declarative knowledge; slow and consciously controlled execution	Much faster; some consistency in automated productions; some parallel processing with familiar productions	Very fast; automatic executions; parallel processing of complex tasks in the domain

This model can be criticized from a number of perspectives: the language is vague and jargon-laden, the use of levels *and* stages is confusing and arbitrary, the lack of clear distinction between some dimensions (e.g., "type of learning" and "cognitive processes") invites speculations of reducing the number of dimensions, and the arbitrariness in declaring six stages (why not 3 or 4 or 5 or 12?) suggests fewer stages might be just as "good." Also, there is a real question whether one can legitimately call either Fitts and Posner's (1967) original theory or Anderson's (1982) extension of it multistage theories.

The key question is whether this model is *useful* for the development of instructional design guidance. The model was considered only marginally useful in this form; however, we are convinced of the basic validity of a multistage model and are intrigued by the potential of such a model to guide instructional design into a greater adaptiveness over the course of skill acquisition. To be both theoretically convincing and practically useful for our purposes, such a model must be more parsimonious, speak more directly to the acquisition of decision-making skills, and give reasonable assurance that the defined stages are indeed identifiable by means of appropriate tests during instruction. Such a model is presented below.

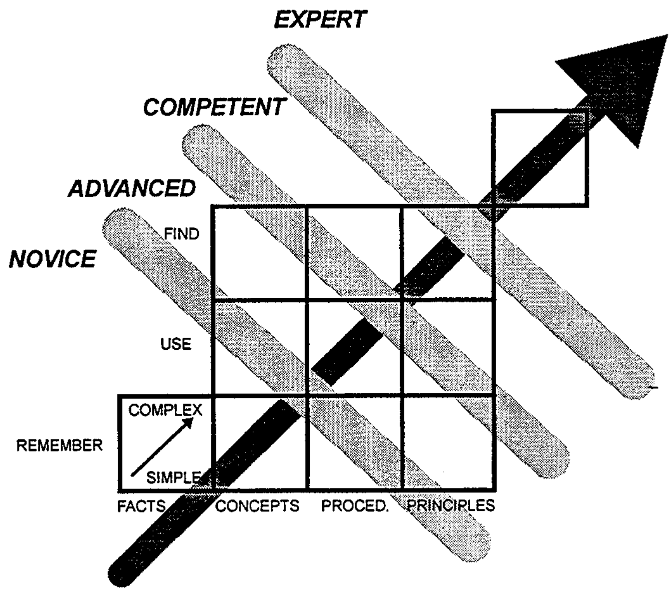
3.3.3. Learning Decision-Making Skills: A Simplified Multistage Model

The simplified multistage learning model presented in Figure 12 is essentially a synthesis of two concepts: the concept of a prerequisite order in the learning process and the concept of multiple stages. These two concepts must be logically related. The prerequisite concept holds that a particular skill can be learned only after its prerequisite skills have been learned. The multistage concept also represents that notion; however, it goes beyond the prerequisite idea by postulating qualitative and quantitative changes not just in the *type* of information that can be processed but in *how* it is processed (e.g., processing changes from serial to parallel; from conscious and analytical control to unconscious, intuitive control; and from very laggardly and laborious to very fast and facile).

The prerequisite notion has been captured in a widely accepted two-dimensional matrix by Merrill (1983, 1978). This matrix relates a "type of content" dimension to a "level of performance" dimension and consists, for the sake of operational utility, of ten discrete boxes. This matrix is usually viewed strictly as a convenient classification scheme. It can also be seen as a map of intellectual skills that must be learned for some terminal objective (i.e., as something like a "learning surface"). When viewed from this perspective, the boxes are regions populated with concepts, procedures, and the like. The boxes are, of course, simplifying constructs with

somewhat fuzzy borderlines that make it practically and theoretically easier to associate particular instructional treatments with particular intersections of content type and performance level.

Figure 12. Simplified Multistage Learning Model



Implicit in this learning surface is the notion that it has to be traversed along a central diagonal vector that originates in the remember-facts cell and points towards the find-principle cell. That is learners cannot acquire a concept on the remember level unless they first acquire its constituent facts, cannot learn to use a concept unless they first acquir the concept on the remember level, and so forth. This central vector leads, in other words, from simple, disjointed knowledge structures to increasingly complex and integrated knowledge structures and from surface knowledge to deep knowledge.

The key to the learning model, shown in Figure 12, is the notion that stages in learning must be defined as partitions of the learning surface. These partitions are not sets of cells but bands of skill aggregates that run orthogonal to the central vector of the learning surface. Within these bands and within the cells included in these bands, one can further postulate a complexity dimension that runs parallel to and in the same direction as the central vector. This dimension simply indicates that simple skills must be mastered before more complex ones. Finally, the performance-content matrix does not include what is generally known as expertise. We concur with Dreyfus and Dreyfus (1980) that the expert "no longer needs principles" and assert that

expertise is in its own category, its own box, which is attached to the upper right-hand corner of Merrill's (1983) matrix.

Based on these ideas and the concepts represented in the earlier UMSA, the learning process for decision-making skills can be divided into four stages. These stages synthesize the prerequisite notion with the multistage notion. They are, like the cells of Merrill's matrix, simplifying constructs which should allow us to associate instructional design guidelines with them. The stages represent levels of decision-making skill that are achievable by learners if they have learned or are learning certain types of content to certain levels of performance. In general, as learners proceed through these stages in the direction of the central vector, knowledge structures become increasingly complex and integrated, and knowledge processing changes from a slow, serial, analytical, rational outcome calculation mode to a fast, parallel, intuitive, recognition-based mode. Specifically, decision-making performance on each of the four stages can be characterized as follows.

- At the NOVICE stage, decision-making performance is constrained by the lack of domain-specific knowledge. The novice is able to solve simple decision problems by applying weak general methods to a domain where they are just beginning to acquire some surface knowledge and where they are best able to use some of the simpler concepts of the domain. Novices are slow and unreliable in recognizing decision problems and cannot judge the available decision window. Their ability to discriminate between salient and nonsalient features of the situation or context is rudimentary. Novices cannot prioritize uncertainty reduction requirements and have no domain-specific strategy for uncertainty reduction. They generate incomplete option sets and, as yet, have no concept of hierarchical classes of options (i.e., the option sets are not ordered in any sense). Work is performed exclusively in an ROC mode.

- At the ADVANCED stage, decision-making performance centers on the use-procedures cell. Learners are now more proficient in using, finding, and defining concepts. Advanced learners begin to invent ways of doing things (find-procedure cell) and, develop a surface understanding of the principles governing the domain (remember-principle cell). Recognition of decision problems is timely and reliable, and judgment of available decision time is usually correct. Learners begin to recognize and utilize salient situation or context features, and they can solve moderately complex decision-making problems in a manner where weak general methods are increasingly supplemented and/or replaced by low-level, domain-specific methods. Learners begin to prioritize uncertainty reduction requirements and to use low-level, domain-specific uncertainty reduction strategies. Complete option sets are identified as well as major classes of options. Work is still predominantly in an ROC

mode, but there are instances of the RB mode being employed with very simple and very frequent decision problems.

- At the COMPETENT stage, learners have become reliable performers. Competent learners are still putting the finishing touches on their ability to use principles and they are achieving competence in inventing/finding procedures or rules. They now are able to focus on situational or context features that are germane to the problem and to modify options to fit these features. Decision problems are recognized quickly and reliably, with knowledge of exactly how much time is available and how to manage time well. Learners develop well-ordered and complete option sets and become efficient in pruning branches or classes with low feasibility, undesirable effects, excessive uncertainty, and so forth, early on. Complex decision-making problems are solved using domain-specific strategies to reduce uncertainty. The predominant working mode is still the ROC mode, but instances of RB decision making are becoming more frequent, especially with simple and moderately complex decision problems that are familiar, have tight time constraints, and involve relatively low stakes.

- At the EXPERT stage, learning is no longer significant. The degrees of automaticity, speed, and reliability continue to rise, albeit more slowly than before. Learners have become accomplished performers. Recognition and timing have ceased to be issues of concern. Experts are able to judge and apply contextual features intuitively and instinctively; thus, they can prune an option tree down to the "first, best" option without ever explicitly constructing the entire tree. In most cases, a satisfactory option simply comes to mind at the same time the decision problem is recognized. Experts are extremely efficient in uncertainty reduction and can "see" entire situation-goal-option patterns based on minimal informational cues. Uncertainty reduction for the expert consists essentially of probing for information to validate a perceived pattern, and of mental simulation (or rehearsal) to ascertain feasibility of the primary option, which is frequently the only option under consideration. Decision makers now work predominantly in the RB mode with some work being accomplished in the ROC mode if time permits, if the stakes are high, and if the problem is new and unusual.

A more concise formulation of these descriptions is presented in Table 5. This table, in conjunction with Figure 12, is hereafter referred to as the learning model for decision-making skills or simply as the learning model.

Table 5. Stages in Learning Decision-Making Skills

	NOVICE	ADVANCED	COMPETENT	EXPERT
Knowledge	General knowledge, rudimentary, unstructured domain-specific knowledge	Domain-specific facts, concepts & procedures, semistructured, loosely interconnected	Full scope of domain-specific knowledge, well structured, highly interconnected	Compiled, highly interconnected domain knowledge
Recognition	Slow, unreliable	Timely, reliable	Fast, reliable	Ahead of the game
Time Line Awareness	None, cannot judge window	Good, usually correct judgment of window	Very good reliable judgment of window	Not an issue anymore
Use of Situational or Context Features	Cannot discriminate significant from insignificant	Can discriminate and apply, albeit not reliably	Discriminates and applies reliably	Extremely acute discrimination based on minimal cues
Prioritizing Uncertainty	Cannot prioritize or estimate	Begins to prioritize	Prioritizes correctly and reliably	Intuitive recognition
Uncertainty Reduction Strategy	Either none or weak general strategy	Low-level, partial domain-specific strategies	Fully developed, domain-specific strategies	Intuitive strategies
Option Set Generation	Incomplete sets, no hierarchy	Complete sets, major classes	Complete sets, full hierarchical structures, early pruning	Only as much as absolutely necessary
Mode	ROC	ROC	ROC/RB	RB
Overall Performance	Slow, analytical, unreliable, extremely effortful, disjointed	Slow, analytical, reliable with simple problems, effortful, serial	Fast, analytical, reliable across spectrum, low effort, serial with parallel episodes	Fast, intuitive, reliable, effortless, absorbed, parallel

3.3.4. Training Considerations

Given the learning model described above, training must be concerned with accomplishing the transitions from one stage to the next in the most expedient, efficient, and effective way possible. Given the usual time and resource constraints under which training must occur, the primary focus of a formal training effort should be on the first two transitions: from novice to advanced and from advanced to competent. The development of expertise (i.e., the transition from competent to expert) requires massive amounts of practice in the actual job environment and is therefore customarily either facilitated by intensive and formal on-the-job training (OJT) or simply ignored. Assuming that the entry-level student falls somewhere in the novice band, formal training should concentrate on facilitating the transitions from novice to advanced (Transition No.1) and from advanced to competent (Transition No. 2). What

foundation of domain-specific knowledge and with the development of domain-specific procedural skills. Transition No. 2, on the other hand, is concerned with refining, integrating, and accelerating domain-specific procedural skills and with the development of the performer's ability to apply knowledge of underlying domain principles to practical decision problems. The learning requirements that must be addressed by the two transitions are therefore fundamentally different.

These differences in learning requirements necessitate differences in instructional treatments or methods. The first transition requires methods that are appropriate for remember-level objectives involving facts, concepts, procedures, and principles for use; find-level objectives involving concepts; and use-level objectives involving procedures. The second transition requires methods that are appropriate for use and find-level objectives involving procedures and principles.

In our case, the choice of instructional methods is constrained by the a priori media choice for the project (i.e., by the requirement to provide instructorless training on a desktop computer). Computer-based instructional media can provide instructional treatment in two basic forms. The first is commonly referred to as computer-assisted instruction (CAI); the second is simulation. CAI implies an instructional environment where a carefully structured sequence of lessons and lesson segments provides training in the building blocks of some terminal skill. CAI also implies that explanations, cues, and memory aids are provided, it implies extensive practice and feedback in component skills. Simulation, on the other hand, implies an emphasis on part or whole task practice in a job-like environment. Explanations, cues, and memory aids are usually absent in simulation per se.

Given the learning requirements for the first transition, we can broadly assert that some form of CAI would be the instructional method of choice. With equally general reasoning, we can assign some form of simulation as the method of choice for the second transition. Simulation would not work for the first transition because of the need to accommodate remember-level objectives and because of the need to train procedures. CAI would work to some extent for the second transition, but it would be very difficult if not impossible to provide a realistically dynamic decision-making environment with this method. Thus, the following instructional design guidelines have been formulated.

Instructional Design Guideline No. 10

🗁 To facilitate Transition No. 1, establish a foundation of domain-specific knowledge and procedural skills using some form of CAI. Transition No. 1 is complete when the learner can reliably solve simple decision-making problems without aid.

Instructional Design Guideline No. 11

🗁 To facilitate Transition No. 2, develop integrated, competent levels of decision-making performance using some form of realistic, dynamic simulation. Transition No. 2 is complete when the learner can reliably solve complex decision-making problems without aid.

Instructional Design Guideline No. 12

🗁 Do not attempt to transition a learner from the COMPETENT stage to the EXPERT stage (Transition No. 3) by means of formal training. Leave the development of expertise to informal OJT.

The efficiency and effectiveness with which the transitions will be accomplished depend heavily on the type and quality of feedback available. The role of feedback in learning decision making is particularly interesting because it is so problematic. Feedback in decision making can of course occur only after the decision point; however, it can occur *before* the start of implementation or *after* the start of implementation. Feedback that occurs prior to implementation is called **a priori feedback** and feedback that occurs as a result of implementation (sometime after implementation has started) is **a posteriori feedback**. A priori feedback basically answers the question of whether the decision maker has made a decision that is both *optimal and logically consistent* with the information that was available prior to implementation. A posteriori feedback provides information on whether the decision was *effective* (i.e., whether things actually worked out the way the decision maker intended). A priori feedback does not occur in the real world; it can occur only in a "training world." Therefore, it has been called **artificial feedback** (Brecke & Young, 1990). In contrast, a posteriori feedback has been called **natural feedback** (ibid). Natural feedback may or may not actually occur in the real world; if it does occur it is often confusing and difficult to attribute to a particular prior decision. The generation of natural feedback (i.e., feedback that has all the

salient characteristics of a posteriori feedback as it occurs in the real world) is usually very difficult in a simulation environment.

Nickerson and Feehrer (1975) point out that in real-world situations decision makers are often evaluated on the basis of a posteriori feedback, that is, on the basis of results (e.g., "What really counts are results"). This is, of course, not very logical in real-world domains where decision outcomes are usually subject to many factors that are beyond the decision maker's control -- perfectly inane decisions may turn up roses and really clever decisions may turn into disasters. Real-world domains are basically open-loop systems, and in open-loop systems the only appropriate manner to evaluate a decision maker is on the basis of a priori feedback. A posteriori feedback is perfectly fine in closed-loop systems where all factors are under the decision maker's control, but such systems are rarely encountered in the real world and especially in the real world of armed conflict.

Frequently, people must learn to make high-risk, high-frequency decisions in a real-world domain (i.e., an open-loop system) without the benefit of instruction. The only type of feedback available to them is a posteriori feedback and, when such feedback arrives, it may not always be clear what it means and/or which earlier decision it belongs to. It is quite possible that a person under this set of circumstances might never even enter a learning process, much less complete it successfully. Of course, this situation can be improved through instruction by providing a priori feedback and by providing strategies to discover and properly assess a posteriori feedback, or by providing both. The following additional guidelines can therefore be formulated:

Instructional Design Guideline No. 13

🗁 CAI for Transition No. 1 must include practice with step-by-step guidance through simple decision problems and with a priori, artificial feedback.

Instructional Design Guideline No. 14

🗁 Simulation for Transition No. 2 must include realistic, unaided practice with both artificial, a priori feedback and natural, a posteriori feedback. As the learner gains proficiency, artificial feedback should be withdrawn.

3.4. WHAT DIRECT INSTRUCTIONAL DESIGN GUIDANCE IS AVAILABLE?

3.4.1. Introduction

The focus now turns to a body of knowledge that concerns itself directly with the design of instruction. Aagard and Braby's (1976) generic instructional strategy for decision making is the most direct guidance available; therefore, it is presented first and discussed in detail. Guidance available from instructional design theories in general are then discussed (Reigeluth, 1983, 1987) and a specific set of theories for the project are selected. Finally, we look at two collections of "heuristics" which together represent knowledge of "what works" (Bennett, 1986; Montague, 1988) in instruction and extract from these collections heuristics that are relevant to training decision-making skills. In other words, this section examines a "mixed bag" of theoretically derived and/or empirically validated guidance that is available to instructional designers who endeavor to train decision-making skills.

3.4.2. Aagard and Braby's Instructional Strategy for Decision-Making Skills

In August 1975, the Interservice Procedures for Instructional Development, also known as NAVEDTRA 106A, were published. This six-volume work was the most comprehensive and detailed attempt undertaken to that date to render the "art" of instructional systems development (ISD) as a set of unambiguous how-to procedures that would enable subject matter experts with very little training to generate reliably effective and efficient instruction. Contained within these volumes are learning guidelines and algorithms for 11 types of training objectives that were developed by Aagard and Braby. These guidelines were also published seven months later in a separate, less voluminous technical report (Aagard & Braby, 1976). One type of training objective that was specifically addressed in these guidelines was decision making. Aagard & Braby identify these guidelines as "general approaches" that are "not at a level that will accommodate any training setting." They also clearly stated that they "are not the product of empirical research but are the product of rational study" and that they had "not been validated" and that "the training system designer should adapt these solutions into more sensitive responses to specific requirements of the learning setting."

Aagard and Braby (1976) first present definitions of the 11 categories of training objectives, then present guidelines for instruction in both prose and flowchart form. We reproduce their definition of the "elemental learning task" MAKING DECISIONS in Table 6 and

provide the prose guidelines after the table. The definition is important because it identifies (under "EXAMPLES") the kinds of decision-making skills that we are targeting in this project.

Table 6. MAKING DECISIONS Described as a Learning Task by Aagard and Braby (1976)

NAMES OF LEARNING TASKS	ACTION VERBS	BEHAVIORAL ATTRIBUTES	EXAMPLES
MAKING DECISIONS	Choose Design Diagnose Develop Evaluate Forecast Formulate Organize Select	1. Choosing a course of action when alternatives are unspecified or unknown 2. A successful course of action is not readily apparent 3. The penalties for unsuccessful courses of action are readily apparent 4. The relative value of possible decisions must be considered -- including possible trade-offs 5. Frequently involves forced decisions made in a short period with soft information	1. Choosing frequencies to search in an Electronic Counter Measures (ECM) search plan 2. Choosing torpedo settings during a torpedo attack 3. Assigning weapons based on threat evaluation 4. Choosing tactics in combat -- wide range of options. 5. Choosing a diagnostic strategy in dealing with a malfunction in a complex piece of equipment 6. Choosing to abort or commit oneself to land upon reaching the critical point in the glide path

Guidelines for Decision-Making Training (Aagard & Braby, 1976):

MAKING DECISIONS

Decision making is defined here as the application of a specific decision model, thought to be useful in diagnosing equipment malfunctions, choosing tactics in Fleet operations, and in planning where several alternatives must be considered, each with an unknown probability of success. The decision model combines the following factors: perception of the problem, identification of alternative solutions, evaluation of these alternatives, and selection of the apparent best solution. Therefore, the guidelines and algorithms presented here support learning to use this decision model.

The decision-making guidelines presented here are based upon the most fashionable practices in existing decision-making training programs. The following guidelines apply to decision-making training.

1. Ensure that the student acquires the **knowledge** required to:

a. identify the problem
b. generate reasonable solutions
c. evaluate these solutions

2. **Decrease student anxiety** to a low level, particularly in the early stages of learning, where student anxiety is high and where complex decisions are to be made.

3. Give the student examples of these two types of **actions which are to be avoided** when making a decision:

    a. The tendency to make a "favorite" decision or to use a "favorite" solution regardless of the real nature of the problem
    b. The tendency to generalize problems or view several types of problems as if they were all the same when, in fact, they are quite different

Give examples of these undesirable responses in decision making.

4. Teach a **decision-making strategy**; the following strategy is suggested:

    a. Upon becoming aware of the problem, define it
    b. Be alert for the availability of relevant information and collect such data
    c. Develop alternative solutions

        (1) State alternative solutions
        (2) Combine alternative solutions
        (3) Compare alternative solutions

    d. Evaluate alternative solutions

        (1) List the probable consequences of each alternative solution
        (2) Rank each alternative solution according to desirability of consequences

    e. Choose course of action based on a desired solution
    f. Execute the chosen course of action

5. Vary the setting of the significant cues of the decision-making learning task. Provide both basic and advanced problems to be solved with a **wide range of problem difficulty** at each level of training for the operational tasks.

6. Ensure the **overlearning** of decision-making skills in later stages of training if the student will be required to perform under stress in the real world.

7. Present the student with a **realistic data load** (i.e., realistic amount of significant data) plus **operational distractors** in real time towards the end of training.

8. Provide the student with **access to potentially relevant data** during practice. In the final stages of training, the data available to him should be limited to that expected in the real-world situations in which he will be working.

9. **Feedback**: Provide the student with answers to the five following questions after his decisions in practice problems. These answers serve as Knowledge of Results (KR).

    a. **Predictability**? (Were problems mistakenly viewed as if they were all the same in reaching solutions?)
    b. **Persistence**? (Was use made of a "favorite" solution when it was inappropriate?)
    c. **Time liness**? (Was this the appropriate time to execute this particular decision?)
    d. **Completeness**? (Was all of the available information considered?)
    e. **Consistency**? (Was the solution compatible with and relevant to the available information?)

Give the KR with respect to the five criteria each time the student makes a decision and, if possible, provide the simulated consequences of the decision as compared to alternative solutions.

This instructional strategy is remarkably comprehensive in terms of the variety of concerns it addresses. Its recommendations have a great deal of face validity, particularly in view of the fact that there was not much of a research base from which to derive that strategy and that its source was apparently nothing more than "most fashionable practice." It is directly applicable only to decision-making tasks where option generation/evaluation is the main problem. Nevertheless, this strategy is a good starting point and it represents the one and only explicitly formulated instructional strategy for training decision-making skills that can be found in the literature. Aside from its relatively narrow range of applicability, there are a number of other points in this strategy that deserve to be highlighted either negatively or positively. On the positive side are the emphasis on ensuring the acquisition of prerequisite domain knowledge, the emphasis on teaching the meta-knowledge of "how to make a decision" and "the mistakes to avoid," and the remarkable detail on ensuring a realistic data load and appropriate distractors during later stages of learning.

There are also several negative side aspects. First is the somewhat inconsistent advice on how to deal with the stress issue. Decreasing the student's anxiety through some instructional manipulation may not be appropriate, particularly when the real setting will be a high-stress environment. Rather, anxiety-promoting conditions may be more useful in training the student in coping strategies. The recommendation to ensure "overlearning" is one possible coping strategy, but it is not the only one and it might be very costly to implement. The treatment of human foibles and inadequacies in decision making is really limited to a guard against inappropriate use of the availability and representativeness heuristics (Kahnemann, Slovic, & Tversky, 1982). However, as Section 3.2 indicates, there is much more that can be -- and probably should be -- added on that score. Then there is a recommendation to provide access to potentially relevant data during practice and to limit that access to real-world levels during later training stages. This is good advice, but it also indicates a lack of recognition for the pivotal role that information acquisition really plays in decision-making tasks. It is paramount that students learn what information sources are available in their real environment, how reliable those sources are, how they can access them, and what the cost of information acquisition is in time and/or other resources. Last but not least, the recommendations for feedback, although interesting, appear to be very difficult to implement (especially predictability, persistance, and completeness). Providing simulated decision consequences is especially difficult and, as discussed in the previous section, might lead to misinterpretations when the consequences are also influenced by factors other than the student's decision.

In short, Aagard and Braby's (1976) strategy, although the best published strategy, is limited. It is perhaps too general to produce reliable training results, however, it provides a good idea of the sort of thing that instructional designers ought to have available. It is a fairly comprehensive collection of instructional prescriptions, but one that is based more on spurious evidence of what works here and there rather than on a cohesive and internally consistent theory of what should work everywhere. Such theories are considered in the following paragraphs.

3.4.3. Instructional Design Theories

The primary purpose of the science of instructional design (ID) is to *prescribe* optimal methods of instruction (Reigeluth, 1983). Of interest in this study are those prescriptive ID theories that can provide guidance for the design of optimal training in decision-making skills. Fortunately, all serious candidate theories that might help us in this regard have been conveniently collected, described, and discussed in two volumes edited by Reigeluth (1983,

1987). These two volumes represent an outstanding integrative effort that provides a comprehensive picture of the current state of the art in ID theory.

All these theories, whether the foundational Gagné-Briggs Theory of Instruction, Gropper's Behavioral Approach to Instructional Prescription, Landa's Algo-Heuristic Theory of Instruction, Scandura's Structural Learning Theory, Collins and Steven's Cognitive Theory of Inquiry Teaching, Merrill's Component Display Theory, Reigeluth's Elaboration Theory of Instruction, or Keller's Motivational Design of Instruction, proceed from the common assumption that different sets of desired instructional outcomes and given instructional conditions require different instructional methods. They also all offer a "language" of concepts and elements of instructional design as well as prescriptions for the optimal arrangement of these elements. There are many overlaps between these theories, and Reigeluth has incisively commented on the similarities and differences of language and prescription offered by these theories.

The fundamental question for the instructional designer who faces this banquet of available theories is whether to select one, synthesize them into a new one, or pick and choose from each. The last alternative is difficult to do systematically unless one uses some set of principles -- some sort of meta-theory. However, such a meta-theory does not exist. The synthesis alternative is desirable but goes far beyond the scope of this project. The only feasible alternative is to select a theory and to use it as the "bedrock" foundation for the design of an instructional method that uniquely fits the desired instructional outcomes and the given instructional conditions or constraints. That does not mean, in our opinion, that one cannot supplement such an approach with principles originating from other theories, especially if the selected theory has missing and/or deficient aspects. This is different from a "pick and choose" approach because it does not rely on one theory as the predominant source of guidance; in fact, it might more appropriately be taken for a synthesis, albeit one that starts with a bias towards one particular theory. This approach, which could be called the "select and supplement" approach, is actually used in this project.

Adopting this approach requires the establishment of criteria for selecting principles. Reigeluth (1983) suggests four criteria for evaluating instructional design theories: (1) comprehensiveness, (2) optimality or usefulness, (3) breadth of application, and (4) parsimony. The comprehensiveness criterion is particularly useful, because it evaluates whether the theory accounts for all "classes of methods": organizational (both macro and micro), delivery, and management. Optimality or usefulness is a rather "soft" criterion because it would seem difficult to determine which theory is optimal for a given purpose unless one actually produces test

samples of instruction and tries them out. Breadth of application refers to the number of conditions "under which the model is optimal" and to the number of desired outcomes "for which it is optimal." This criterion falls into the same trap of requiring an empirical test, but it can be used if "for which it is optimal" is replaced with "for which it is designed." Parsimony, finally, is always an admirable criterion, especially when one does not have much money.

We have made our selection on the basis of comprehensiveness, parsimony, and logical clarity and have decided to use Reigeluth's Elaboration Theory for the macro aspects of instructional strategy and Merrill's Component Display Theory for the micro aspects. These two theorists have in fact collaborated to produce a complementary theoretical framework that provides, in combination, the most comprehensive and the most clearly and simply articulated guidance available. However, neither of these two complementary theories deals with the motivational aspects of instruction in any more than cursory form. We therefore supplement these two theories with Keller's ideas for the motivational design for instruction. With this decision, we have available to us a comprehensive set of prescriptive principles that can provide guidance in the design of the macro and micro aspects of an instructional strategy tailored to the requirements of training decision-making skills.

Contrary to the Aagard and Braby guidelines, the Reigeluth-plus-Merrill-plus-Keller (RMK) guidelines are focused exclusively on the issues of HOW to teach rather than on WHAT to teach, and they do provide more detail, more breadth, and more discipline in this respect. What the RMK guidelines are and how they can be applied to the design of an instructional strategy for decision-making skills will be discussed in the next section of this paper. Before we turn to this next section, however, we shall examine one last set of sources that yield additional guidelines for our purpose.

3.4.4. Instructional Engineering Heuristics

In 1986, the U.S. Department of Education published a booklet entitled: "What Works: Research about Teaching and Learning" (Bennett, 1986). This precipitated the development of a very similar document entitled: "What Works: Summary of Research Findings with Implications for Navy Instruction and Learning" (Montague, 1988). The first document addresses research findings that apply to the teaching and learning of children (i.e., to primary and secondary education). The second document addresses research findings that apply to the teaching and learning of adults, which makes this latter document particularly relevant for our purposes. Both documents present collections of what Montague (1987) has called "instructional

engineering heuristics" or guidelines for the arrangement of instruction. Each guideline is based on reliable research findings that have been confirmed repeatedly in different circumstances. Montague's "What Works" collection, like Bennett's collection, is subdivided into heuristics that work for training executives, for instructors, and for training specialists. Nineteen out of 48 of these heuristics are directly applicable to our project. Most of these heuristics confirm guidance already obtained from other sources. However, there is one that is viewed as particularly useful: the use of mental models in training and performance. We present this entire heuristic in Table 7 to introduce its technical content and to show how these heuristics are presented. We also present the research findings for each of the 19 heuristics and describe how we intend to apply them to the design of the instructional strategy for decision making (Table 8).

Table 7. Instructional Design Heuristic after Montague (1988)

Promote Development of Mental Models

Finding:	When students are asked to act in accordance with a prescribed "model" of performance, they develop conceptual understanding that guides competent performance more effectively.
Comments:	Learning involves the development of qualitative conceptual structures that are called "mental models." A person makes use of an internal model of the world to understand, explain, and predict things about the world. If people carry a small-scale model of external reality in their heads, they are able to try out various alternatives, decide which of them is best, react to future situations before they occur, and utilize knowledge of past events in dealing with the present and future. Models allow people to generate descriptions of system purpose and form or explain system functioning and observed states, and to make predictions of future states. These models provide a means for organizing and reorganizing memory and deciding on actions. Mental models evolve naturally through the interaction of the learner and particular environments. If this is so, we can devise methods to promote their development. One way is representing the functionality of the work environment and the devices/equipment in it. In addition, providing external guidance or directions (i.e., telling what to do and how to do it) allows the buildup of experience coupled with important cognitive information that, once internalized, will guide performance. An accurate mental model develops from the way events flow on-the-job, how devices function and can malfunction, and serves as the scheme to guide personal action when new problems are encountered. Having students describe in detail the steps they're using while performing identifies errors, develops competence faster, and transfers readily to the work environment. As an example, consider the task of training students to solve problems in electric circuits, thermodynamics, or mechanics. By guiding students through the steps, explaining why they're taken, then having students describe the factors and their interactions as they solve subsequent problems, they learn rapidly and accurately. Instructors can check the accuracy of students' initial representation and provide feedback. It focuses students' attention on the need for careful representation of all facets of the problem and provides the basis for correct solutions. Thus, by concentrating on accurate initial description of the problem, students learn to internalize the procedures as part of their mental model, which they use habitually in approaching later problems.
References:	Anderson, R. C (1977). The notion of schemata and the educational enterprise: General discussion of the conference. In R. C. Anderson, R. J. Spiro & W. E. Montague (Eds.), *Schooling and the acquisition of knowledge* (415-431). Hillsdale, NJ: Erlbaum Associates 415-431. Gentner, D., & Stevens, A. L. (1983). *Mental models.* Hillsdale, NJ: Erlbaum Associates. Heller, J. I., & Reif, F. (1984). Prescribing effective human problem-solving processes: Problem description in physics. *Cognition and Instruction, 1(2), 177-216.* Kieras, D. E. (in press). What mental model should be taught: Choosing instructional content for complex engineered systems. In J. Psotka, D. Massey, and S. Mutter (Eds.), *Intelligent tutoring systems: Lessons learned.* Hillsdale, NJ: Erlbaum Associates.

Table 8. Research Findings and Comments from "What Works" (Montague, 1988)

No.	Research Finding	Comments
1	Students learn the same content as well or better from computer-based instruction as in a regular classroom situation and complete the lessons faster; course materials can be widely distributed and given at any time.	This simply supports the idea for a desktop computer-based trainer. The cost effectiveness of the trainer will be largely dependent on how widely distributed it is.
2	Students can learn as well from structured instructional material and self-study as from conventional classroom procedures.	This confirms the above. The training system will incorporate a structured course for self-study (i.e., a CAI component).
3	When instruction gets the student's attention, is perceived as relevant and as having attainable goals, and provides frequent testing and explanatory feedback, students work hard, achieve well, and enjoy learning.	These are the essential tenets of Keller's Motivational Design for Instruction (the K in RMK).
4	Students learn best when instruction is adapted to their existing knowledge and background.	All students will be C^2 personnel. The subject matter will be an artificial or fictional C^2 domain.
5	Students who spend as much time as possible actively engaged in learning learn more than students who do not.	Instruction in both the CAI component and the Simulation component will be continuously interactive.
6	Students perform best when their instructors inspire them to take an active role in their learning.	The instructional strategy will incorporate options for various levels of learner control.
7	Learning improves when students know how to set and achieve their own goals.	The instructional strategy will incorporate options for various levels of learner control.
8	Diagrams, graphs, photographs, and illustrations can improve student learning.	Such devices will be used where appropriate. They are standard ingredients of well-designed instructional materials.
9	Enhancement of text in books or manuals through orientation, summaries, examples, and diagrams can aid student comprehension and learning.	These kinds of enhancements are already part of the RMK guidelines and they are customarily employed in CBT.
10	When students act in accordance with a prescribed "model" of performance, they develop conceptual understanding that guides competent performance more effectively.	Instruction will include mental models for decision making and for systems and processes describing and explaining the technical domain.
11	The ways students study influence what and how much they learn. Students can learn effective study strategies.	This suggests the inclusion of objectives and content dealing with study skills for decision making with the device we are building.
12	Providing students with representative good examples and contrasting them with bad examples teaches them the desired knowledge and skills.	This is part of Merrill's Component Display theory (the M in the RMK guidelines).
13	Practicing lesson-related tasks promotes learning new skills.	Levels of practice will be one of the major strategy variables that can be controlled.
14	Students learn and retain knowledge and skills best when the learning environment incorporates the critical, functional features of the working environment.	The critical, functional features for a working C^2 decision-making environment are the eliciting stimuli, the available information resources for the reduction of uncertainty, the response tools, and the feedback stimuli. They will be replicated in the training environment with functional rather than physical fidelity.

Table 8. Research Findings and Comments from "What Works" (Montague, 1988) (Continued)

No.	Research Finding	Comments
15	A simulator's effectiveness is a function of the instructional methods incorporated into it to support student learning; design decisions, therefore, must be related to the cognitive processes required to learn the task.	This is precisely the reason we are developing this paper and the reason we will develop our design for the simulation module based on guidelines developed here.
16	Effective simulation provides systematic practice and feedback about errors, depicts how a device or system works, and may violate physical and temporal fidelity.	Systematic practice and feedback are part of the RMK guidelines. The "system" will be artificial (i.e., it will violate physical fidelity).
17	Frequent, systematic testing and assessing of student progress informs students about their learning and informs instructors and managers about strengths and weaknesses in student learning and the instruction.	Frequent, systematic testing will be part of the instructional strategy.
18	Students who receive constructive feedback about the accuracy and adequacy of their performance become more interested in the class and learn more.	Constructive feedback will be a motivational aspect of the instructional strategy.
19	Maintaining critical skills requires systematically planned and monitored on-the-job rehearsal and testing.	The training system we are building makes skill maintenance in decision making a practical possibility. It will be up to the users to avail themselves of it. This finding provides support for leaving the development of expertise to OJT.

3.4.5 Training Considerations

This section deals with training considerations and examines three sources: an off-the-shelf strategy, instructional design theories, and two collections of instructional engineering heuristics that work in a wide variety of circumstances. These three sources offer a plethora of often redundant instructional recommendations that could easily be consolidated into a smaller, more manageable set of nonredundant instructional design guidelines. There is one encompassing and general guideline that is based on the choice of instructional design theories made above:

Instructional Design Guideline No. 15

🗁 Design the organizational strategy for training decision-making skills using Reigeluth's elaboration strategy as guidance for the macro strategy and Merrill's CDT for the micro strategy. Complement either with elements based on Keller's theory on motivational design of instruction.

This guideline implies, of course, entire sets of more specific instructional design guidelines. These lower-level guidelines are not reproduced here but are referred to in Section 4.0, which focuses on the actual application of all guidelines developed in Section 3.0 (the present section). The four guidelines below are more specific than the guideline above, and they relate primarily to the micro aspects of instruction. They are, in all cases, guidelines that have been consolidated by summarizing several guidelines from either Aagard and Braby or Montague, or from both. The source of each guideline is indicated in parentheses. When a guideline corresponds to a more specific guideline from Reigeluth's, Merrill's, or Keller's theories, the parentheses include an R, M, or K, as the case may be.

Instructional Design Guideline No. 16

🗁 Training content should include relevant technical domain knowledge and meta-knowledge on decision making. Where appropriate, the content of either type should be cast in the form of mental models of prescribed performance. Where appropriate, such content should also include contrasting good and bad examples. Training content may inelude study skills.

(A&B: 1.,3.,4.; Mont.: 10, 11; M)

Instructional Design Guideline No. 17

🗁 Practice should be realistic and frequent, cover a wide range of difficulty and significant cues, and provide constructive feedback that is directly related to training objectives.

(A&B: 5. through 9.; Mont.: 13 through 18; M)

Instructional Design Guideline No. 18

🗁 Enhance student motivation by getting the student's attention, establishing relevance, setting attainable goals, providing for ample practice and feedback, and permitting learner control whenever possible.

(Mont.: 3 through 7, K)

Instructional Design Guideline No. 19

🗁 Enhance the presentation of instructional content with orientation aids, summaries, and syntheses, and with clear, appropriate illustrations of various types.

(Mont.: 8, 9: M, K)

Instructional Design Guideline No. 20

🗁 During early stages of learning, student anxiety should be kept low. Later stages of learning should begin to introduce realistic levels of stress.

(A&B: 2.)

IV. APPLICATION

4.1. INTRODUCTION

This section attempts to apply the instructional design guidelines developed in the preceding sections to the logistics training problem. Before doing so, it is useful to articulate the problem once again: We are searching for an optimal method to train decision-making skills under certain conditions and constraints. The conditions and restraints are given by the target population of learners, by the subject matter domain, by the training goal, and by the teaching agent or delivery medium:

- The **learners** are adult military or civilian personnel who will occupy positions with decision-making functions in Command and Control (C^2) agencies during times of heightened tension, crisis, or war. They may or may not occupy the same positions during peacetime.

- The **subject matter domain** in its most general form can be described as C^2 and in more specific form as Logistics Command and Control (LC^2), where decision making is concerned with the assignment of resources to operational demands on the basis of multiple, often interrelated factors.

- The **training goal** is to achieve a level of learner decision-making skill that will enable learners to function at high levels of effectiveness immediately upon occupying C^2 positions under operational conditions. This level of skill is identified as the COMPETENT stage in the learning model presented in Section 3.3.

- The **teaching agent** or **delivery medium** is an IBM PC-compatible, 386-based desktop computer with a color monitor available under the DESKTOP III procurement.

The strategy for the pursuit of the optimal training method is to first reduce the search space by theoretical analysis, to formulate a strawman methodology based on the results of the analysis, and finally to refine the strawman methodology through empirical trials. We have

presented the theoretical analysis in the preceding sections and are now ready to formulate a strawman instructional method.

To define an instructional method, strawman or otherwise, one must specify organizational, delivery, and management strategies (Reigeluth, 1983). In our case, the delivery strategy is essentially predetermined (desktop computer-based training). That leaves organizational and management strategies as open issues. In this section, we define a strawman organizational strategy and deal with the issue of management strategy in the context of needs for empirical research.

The remainder of this section consists of four parts. The first part deals with the training target. It begins with a discussion of what types of decision-making tasks warrant the expenditure of training resources and ends with the specification of the terminal training objective for the system to be built. The second part specifies the content of the training. The third part outlines the strawman organizational strategy for training decision-making skills on both a macro and micro level. The fourth and last part provides a brief overview of some major research issues that will have to be investigated along the road to the optimal instructional strategy for decision training.

4.2. TRAINING TARGET

Training, especially in times of limited funding, should concentrate on those types of decision-making tasks that represent the most "lucrative targets" for training. Clearly, decision-making tasks that are frequently performed by many people, that are difficult to learn and perform, that involve high stakes, and for which there is currently no adequate training are lucrative targets. They are likely to show a greater return for any investment in training than tasks with the opposite characteristics. This means, in practical terms, that the decision-making tasks performed by a single Commander-in-Chief (CINC) are probably less appropriate targets for training than the many decisions made every hour by the many captains, majors, and lieutenant colonels at lower levels of the military C^2 hierarchy. There may be much more at stake and it may be much more difficult to make CINC decisions and to learn to make them, but one can safely assume that one does not become a CINC unless one demonstrates high levels of skill in decision making along the way.

Decision-making tasks that score high on task frequency, number of performers, difficulty to learn and perform, mission criticality, and inadequacy of current training are easily

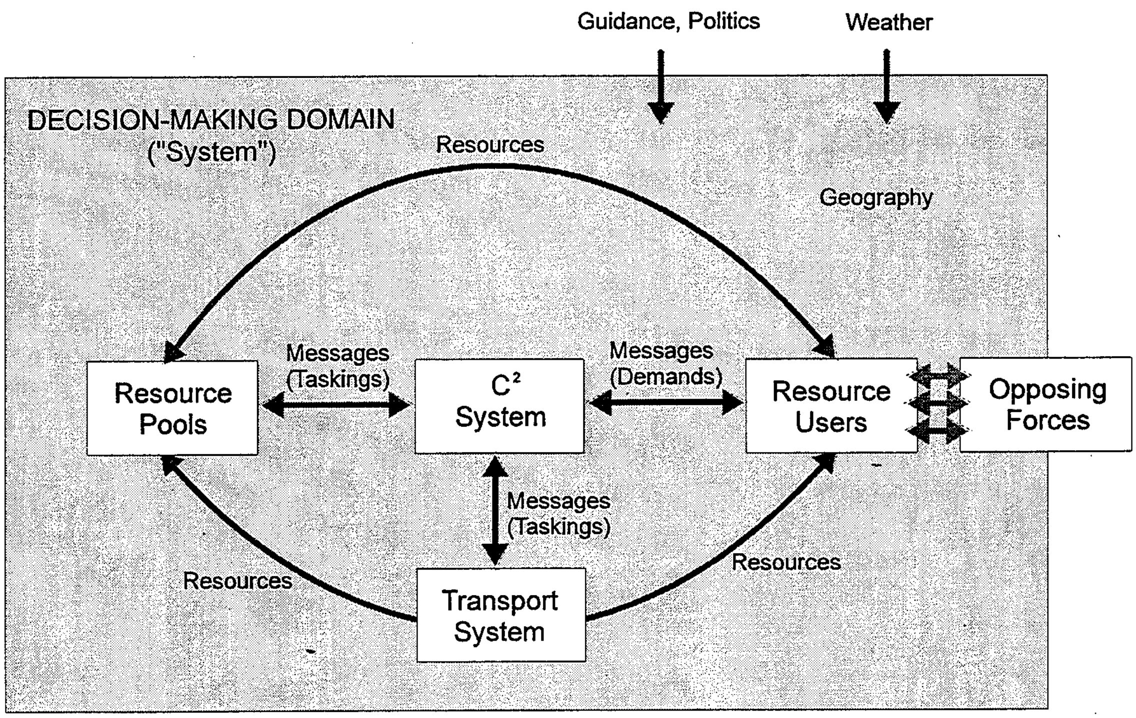
found in C^2 agencies (Brecke et al., 1988; Schwaninger et al., 1991). Within such agencies one generally finds these tasks at the mid-management level. This was confirmed during site visits at Headquarters Air Force Logistics Command (AFLC), Air Logistics Center (ALC) Ogden, and ALC Warner Robins. Decision-making tasks with the desired characteristics were easily found at the ALCs in positions with three- and four-letter office symbols. They appeared to be less frequent at higher levels within the ALCs, and they were not found at all at Headquarters AFLC.

On the surface, there seems to be an endless variety of decision-making tasks, but this variety likely can be reduced to a manageable number of categories. One notable attempt to categorize tactical decision-making tasks was the ACADIA taxonomy proposed by Sidorsky and Houseman (1966) in which decisions were classified as acceptance, change, anticipation, designation, implementation, and adaptation decisions. Although the ACADIA scheme is less than convincing, there is no reason tactical decision problems cannot be reduced to a few "classical" types. We believe we have identified one such type with certainty (which is of course a long way from an exhaustive taxonomy). We have called this type of tactical problem the **"Demand and Supply"** (DS) problem.

The DS problem arises when operational units request resources. The decisions that must be made either deal with ways and means to satisfy a given request or, if requests are competing for limited resources, with distribution of resources over a number of requests. An example of the latter is a situation in a theater where several users (wings, squadrons) request more ammunition of a certain type than can be provided in a certain time frame. This situation requires a decision that basically answers "who gets what, when." A schematic representation of this type of decision-making problem is provided in Figure 13.

The diagram shows Resource Users that are combat units (such as divisions, wings, squadrons, etc.), a C^2 System that can be elaborate (such as a single mode or multiple nodes), Resource Pools (such as depots, air logistics centers, wings, etc.), and a Transport System (that can be more or less involved and includes air, sea, and land transport units). Decisions are triggered by request messages coming from resource users into the C^2 system where the decision maker sits. The decisions made by the latter are implemented by means of messages that task resource pools and the transport system to provide resources. These messages then trigger a flow of resources to the requesting user. The entire system is embedded in an environment that is subject to a number of uncontrollable factors such as the actions of the opposing forces, politics, weather, geography, and so on.

Figure 13. Schematic Representation of the Decision-Making Domain for the Targeted Class of Decision-Making Tasks



This type of decision problem occurs in many manifestations in all services and on many levels. For example, it occurs at air support operation centers, where Army units request air resources. It is, without a doubt, a universal type of tactical decision-making problem. It is also a decision task that definitely has a very high frequency of performance, a high number of performers, can quickly become very difficult to perform and difficult to learn, involves high stakes, and is (in most cases) very poorly trained, if at all. This type of decision-making task is therefore clearly the right kind of target for this project and is, in fact, the task type we will be focusing on.

The Terminal Training Objective for the project can be formulated as follows:

TERMINAL TRAINING OBJECTIVE	
Action	• The student will make and implement decisions
Conditions	• given demand-and-supply problems presented within the context of a computer-based conflict simulation, where the problems have the same time line and uncertainty profiles as the real-world target tasks • and given eliciting stimuli, information resources, and response implementation facilities that are functionally equivalent to those of real-world tasks
Standards	• with the student's decision being: • reliably effective, • logically consistent with available information, and • within the available time window.

4.3. TRAINING CONTENT

The next area of concern is the content of instruction. There are basically two major issues that must be decided by the instructional designer. The first is the meta-content issue which deals with whether instruction should include content about decision making in general. The second is the domain content issue, which deals with whether content should be tailored to each specific domain in which the targeted task type occurs and with what should be included or excluded from domain content.

4.3.1. Instructional Design Guidelines

A number of the instructional design guidelines developed earlier bear on the content issue. These guidelines are reproduced in Table 9.

Table 9. Instructional Design Guidelines Relevant to the Training Content Issue

Instructional Design Guidelines for Training Content
Guideline No.
1. Include in the training system the capability to train students in the use of the uncertainty and time line models.
5. Train students how to avoid and/or overcome deficiencies by using practice situations in which deficiencies are likely to show up.
6. Train students to cope with limitations by including explanations, procedural aids, and appropriate practice and feedback in situations where limitations are likely to manifest themselves.
9. Include in the training system the capability to train students in using the process model for decision making.
10. To facilitate Transition No. 1, establish a foundation of domain-specific knowledge and procedural skills using some form of CAI. Transition No. 1 is complete when the learner can reliably solve simple decision-making problems without aid.
16. Training content should include relevant technical domain knowledge and meta knowledge on decision making. Where appropriate, the content of either type should be cast in the form of mental models of prescribed performance. Where appropriate, such content should also include contrasting good and bad examples. Training content may include study skills.

4.3.2. Application

Four types of meta-content can potentially be included in training. These are presented below.

1. **Decision-making models** refers to the kind of knowledge Aagard and Braby (1976) call "decision-making strategy." It is the kind of knowledge represented by the uncertainty, time line, and process models, and it includes the notions of novice (ROC process) versus expert (RB process) decision-making.

2. **Human Performer Models** refers to knowledge regarding human strengths and weaknesses (deficiencies and limitations) in decision making. It also refers to

knowledge of *methods* for avoiding human foibles and for capitalizing on human strengths.

3. **Management Skills** refers to methods for managing one's own cognitive and affective resources for optimal performance under stress.

4. **Study Skills** refers to methods for using the training system to one's own best advantage.

The issue that needs to be decided is whether one or more of these types of meta-content should be included in instruction. On principle, one would, of course, opt for inclusion if such content increases instructional effectiveness and/or efficiency. Whether knowledge of meta-content makes a difference in the rate of skill acquisition and/or in long-term performance is ultimately an empirical question. There are very good logical and empirical reasons to believe that meta-content could be helpful, particularly the decision-making models presented in this paper. Meta-content helps direct the student's and the performer's attention and effort and has been found beneficial in a variety of studies on problem solving and troubleshooting. Since the available evidence is not conclusive and the training system is intended as a research test-bed, there is no need to decide this question on an a priori basis. The training system will simply have to be designed such that various types of instructional treatments can be "dialed up," and this capability will simply have to include the individual addition or deletion of each of the four types of meta-content.

But what about domain content? Domain content is the technical knowledge of the decision-making domain (i.e., the facts, concepts, procedures, rules, principles, mental models, and so on, that describe the objects in the decision-making domain and their interrelationships). Clearly, this type of knowledge is a prerequisite for instruction for decision-making skills; that is, students must either have it or learn it. Unfortunately, this type of content is beset with significant problems: it is full of local differences (i.e., it is very different for each C^2 agency and for each position) and it is very unstable (i.e., it changes very frequently). Accommodating a wide range of content variations and keeping up with all content changes would be logistically difficult and prohibitively expensive.

If "real" domain content (i.e., a real domain) cannot be used, what then? The decision maker must make decisions about something; that is, this person must operate in *some* domain. The choices are to use either a domain that is very stable and common or one that is artificially

created. The disadvantage of a stable, common domain is that the students would already possess the prerequisite domain knowledge. The effect of variations in prerequisite training could therefore not be investigated with such a system. That leaves the choice of an **artificial** domain which is functionally and physically similar to a number of real domains.

A decision to go with an artificial domain has transfer of training implications that must be clearly spelled out. The argument is that people can be trained to be better decision makers in the real world through training in an artificial world, as long as the practice tasks and the real-world tasks have the same critical features. The uncertainty and time line models provide the tools to ensure training tasks and job tasks are indeed rigorously similar in all essential aspects. As long as this similarity can be maintained, there is no reason to expect anything other than positive transfer of training from the artificial world to the real world. The question is not the direction but the degree of transfer and thus the cost vs. benefit ratio. Of course, it may be argued that any benefit is worth the cost because the cost of the alternative (i.e., the cost of developing and maintaining multiple high-fidelity simulations) is prohibitive.

Besides the risk of low transfer, there is another downside. If the training system incorporates an artificial domain, it will do nothing to alleviate the training problem C^2 units have with respect to "local" domain knowledge. The training system was, at least initially, seen as a means to provide the entire spectrum of training from simple factual domain knowledge to the pinnacle of decision-making skills under high-stress, war-like conditions. The decision to go to an artificial training world enables the system to provide the upper end of the training spectrum, but it eliminates its capabilities at the lower end. This is essentially the price for a system that is instantaneously applicable to any real domain where the targeted task type occurs, as opposed to a system that can do "cradle-to-grave" training but only in a very narrow, specialized domain and only if it is constantly updated.

Whether the domain represented in the training system will be artificial or not, the learner must acquire a functionally accurate mental model of the domain within which they will have to make decisions. What is meant by such a model is shown in Figure 13, where the general structure of the "system" is depicted, within which the target class of decision tasks must be performed. This model represents the highest level of content or domain knowledge that the learner must have readily available. All other content can essentially be deduced from this model. For example, the learner has to have more detailed models for all the subsystems (boxes) in the diagram. The learner must know the features, capabilities, and limitations of object classes and individual objects in each subsystem. They must know how objects within the subsystems

and across subsystems interact. They must know everything that will usually affect a decision within the domain and quite a few things that will rarely or never have any bearing on a decision. They must also be able to tell the necessary from the unnecessary knowledge because that is one problem encountered in the real world.

The entire content issue can be summed up as follows.

1. The content of instruction must at least include domain content and may include meta-content.

2. The technical decision-making domain will be an artificial domain with the same structural and functional characteristics as the real domains in which the target type of decision-making task, the "demand and supply" task, occurs.

3. Domain content will consist of "mental models" of the decision-making domain and of the constituent facts, concepts, procedures, and principles.

4. Meta-content consists of four types. The training system will allow the inclusion of one or more types of meta-content, depending on research objectives.

4.4. TRAINING STRATEGY

This section addresses the organizational strategy for training decision-making skills. We begin by recalling the instructional design guidelines developed earlier, then progress to strawman macro-and micro-organizational strategies. The purpose of this report is to provide generic rather than specific strategies. The intent is to describe the principle rather than to show the details of its application to a specific, invented, artificial domain. Application details will be the topic of future technical reports.

4.4.1. Instructional Design Guidelines

Most of the instructional design guidelines developed in the section on theoretical foundations apply to the issue of organizational strategy. For the sake of convenience, these guidelines are reproduced in Table 10.

Table 10. Instructional Design Guidelines for Organizational Strategy

Instructional Design Guidelines for Organizational Strategy	
Guideline No.	
2.	Ensure that practice problems have the same uncertainty and time line profiles as the target job tasks.
3.	Ensure that training provides for a practice environment that features the same types of information sources and requires the same kinds of information access procedures as the target environment.
4.	During practice, gradually increase time constraint, complexity, and uncertainty to levels encountered in the target job environment.
5.	Train students how to avoid and/or overcome deficiencies by using practice situations in which deficiencies are likely to show up.
6.	Train students to cope with limitations by including explanations, procedural aids, and appropriate practice and feedback in situations where limitations are likely to manifest themselves.
7.	Provide high levels of increasingly complex practice in realistic decision-making situations.
8.	Adapt instructional treatments to learner proficiency by gradually compiling and finally withdrawing instructional cues.
10.	To facilitate Transition No. 1, establish a foundation of domain-specific knowledge and procedural skills using some form of CAI. Transition No. 1 is complete when the learner can reliably solve simple decision-making problems without aid.
11.	To facilitate Transition No. 2, develop integrated, competent levels of decision-making performance using some form of realistic, dynamic simulation. Transition No. 2 is complete when the learner can reliably solve complex decision-making problems without aid.
12.	Do not attempt to transition a learner from the COMPETENT stage to the EXPERT stage (Transition No. 3) by means of formal training. Leave the development of expertise to informal OJT.
13.	CAI for Transition No. 1 must include practice with step-by-step guidance through simple decision problems and with a priori, artificial feedback.
14.	Simulation for Transition No. 2 must include realistic, unaided practice with both artificial, a priori feedback and natural, a posteriori feedback. As the learner gains proficiency, artificial feedback should be withdrawn.
15.	Design the organizational strategy for training decision-making skills using Reigeluth's elaboration strategy as guidance for the macro strategy and Merrill's CDT for the micro strategy. Complement either with elements based on Keller's theory on motivational design of instruction.
17.	Practice should be realistic and frequent, cover a wide range of difficulty and significant cues, and provide constructive feedback that is directly related to training objectives.
18.	Enhance student motivation by getting the student's attention, establishing relevance, setting attainable goals, providing for ample practice and feedback, and permitting learner control whenever possible.
19.	Enhance the presentation of instructional content with orientation aids, summaries and syntheses, and with clear, appropriate illustrations of various types.
20.	During early stages of learning, student anxiety should be kept low. Later stages of learning should begin to introduce realistic levels of stress.

4.4.2. Application: Macro Strategy

For the macro aspects of organizational strategy, we rely on Reigeluth's Elaboration Theory (ET) as the primary organizational principle. This theory integrates and synthesizes instructional sequences proposed by a number of other researchers (e.g., Ausubel, Bruner, Scandura, Merrill, and Norman) "into an internally consistent set of prescriptions that were all guided by the goal of building stable cognitive structures in a meaningful, subsumptive (Ausubel), or assimilative (Mayer) way" (Reigeluth, 1987, p. 245). It provides an admirable level of operational guidance for instructional designers in "selecting, sequencing, synthesizing, and summarizing instructional content" (Reigeluth, 1987, p. 245). It explicitly addresses interrelationships within instructional content, and it is the only theory that "specifically allows for some learner control over the selection and sequencing of the content" (Reigeluth, 1987, p. 246).

Reigeluth's ET prescribes seven major strategy components (p.247):

1. An elaborative sequence for the main structure of a course (and curriculum)
2. A variety of prescriptions for sequencing within individual lessons of a course (including learning prerequisite sequence)
3. Summarizers
4. Synthesizers
5. Analogies
6. Cognitive strategy activators
7. A learner control format

The key prescription is the elaborative sequence, which is a simple-to-complex sequence that begins instruction with:

> a special kind of overview containing the simplest and most fundamental ideas, called the "epitome" (because it epitomizes the content). Then, subsequent lessons add complexity or detail to a part or aspect of the overview in layers (called "elaborations").

Reigeluth is fond of using a zoom lens analogy to explain the concept: one starts with a simplified overview representing the "big picture" (perhaps something like the picture presented in Figure 13) that is the epitome. Subsequent lessons then zoom in on the parts of that picture

and present increasingly more elaborate pictures of the parts. This "zooming" or elaborating continues in layers or levels until the required level of detail and/or complexity has been reached.

The elaborative strategy makes intuitive sense, has considerable theoretical and empirical support (Reigeluth, 1983), and fits the instructional problem we are attempting to solve. That learning should proceed from the simple to the complex is simply a matter of common sense. Our limited information processing capabilities demand that complexity be built up gradually; at the beginning, the learner will only understand and retain simple things. That a simplified overview, an epitome, should be that beginning is logically convincing and supported by cognitive learning theories which argue that the epitome provides a scaffold for the integration of the elaborations to follow. This integration is further supported by the use of the synthesizer and summarizer elements. Elaborative sequencing starting with an epitome can be applied very neatly to the training of decision-making skills: the learner begins by making the least complex decisions possible and progresses through levels of elaboration to increasingly complex ones. The decisions at the beginning should at once be simple and represent the essence of the type of decision-making tasks that will be encountered in the job being trained for; that is, they should "epitomize" the task to be learned.

Reigeluth has refined the concept of an elaborative sequence into specific sets of prescriptions that apply to three different types of content: conceptual, procedural, and theoretical content. Consequently, he distinguishes between **conceptual**, **procedural,** and **theoretical** elaborations. He further proposes that the entire content of instruction towards a particular goal should first be organized on the basis of a single type of elaboration that fits the primary content of the instruction, which is then called the **organizing content**. All other content is called **supporting content** and is "plugged into" the skeleton of the organizing content wherever it is most relevant.

The organizing content for training decision-making skills is probably best characterized as procedural content that should be organized along the lines of a procedural elaboration. The following paragraph, quoted from Reigeluth (1987), explains the notion of procedural elaboration:

> Procedural Elaboration. On the other hand, the goals of your course might be primarily procedural(addressing the "how"), as in an English composition course. In this case the elaboration sequence should follow the optimal process of *procedural* skill acquisition. Your first activity as a designer is to identify the simplest possible version of the task (usually equivalent to the shortest "path" through the procedure in P.F. Merrill's 1980

path analysis methodology) and to identify the "simplifying assumptions" that define that simplest version. Your next task is to design the instructional sequence by gradually relaxing the simplifying assumptions in the order of most important, comprehensive, and fundamental ones first, such that progressively more complex paths are taught. Then, the other types of content, including concepts, principles, learning prerequisites and remember-level information, are "plugged into" that sequence at the point where each is most relevant. (p.249)

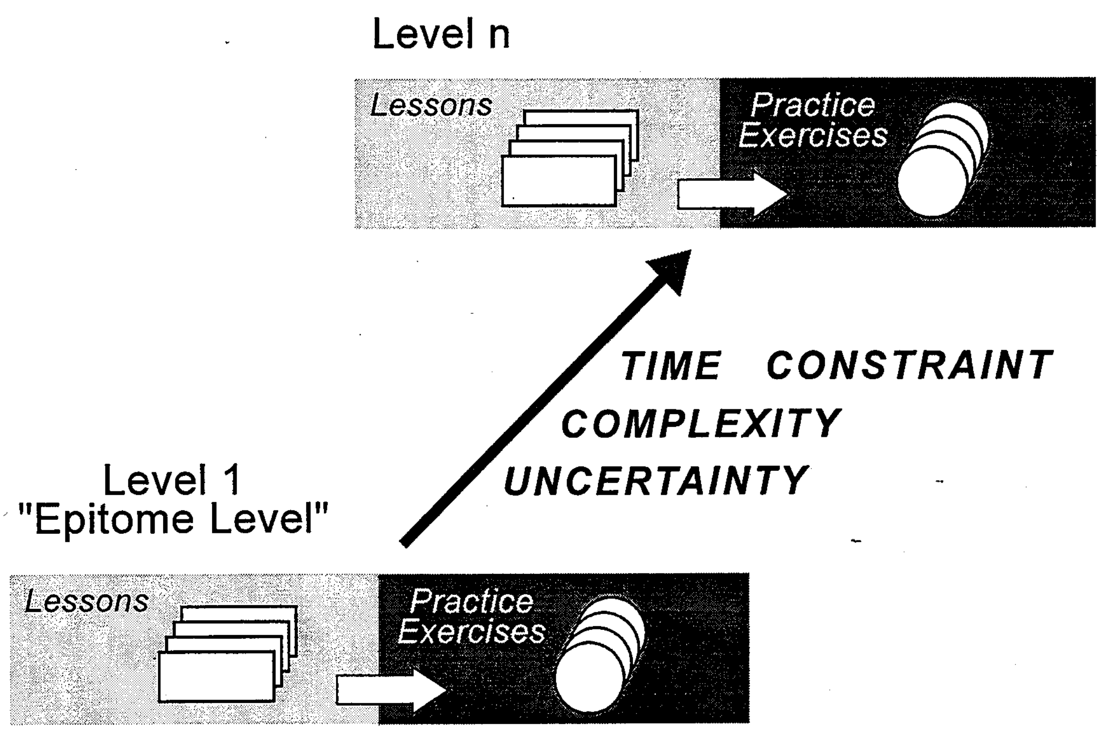
The entire content of a course of instruction in decision making can thus be organized in **levels** where students on the first or epitome level to make the simplest types of decisions that are possible in a given domain and where they learn to make more and more complex decisions on subsequent levels of elaboration.

The notion of levels of elaboration is compatible with the multistage learning model presented in Section 3.3. The macro aspects of organizational strategy can be organized so that learners progress *on each level* from the NOVICE stage to the COMPETENT stage. Learners thus first become competent decision makers in the simplest and most "benign" version of a particular domain, then progress to the next level, where they are exposed to a more complex and less benign version of the same domain, and so forth. On each next higher level, learners are again NOVICEs with respect to new facts, concepts, procedures, and principles that they must first acquire then apply to the more complex, more uncertain, and more time-constrained decision-making situations on that level until, eventually, they are COMPETENT on that level.

Each level must therefore provide appropriate instruction to facilitate Transition No. 1 (NOVICE to ADVANCED), then Transition No. 2 (ADVANCED to COMPETENT). Guidelines No. 9 and 10 prescribe some form of CAI for Transition No. 1 and some form of realistic dynamic simulation for Transition No. 2.

Consequently the strawman macro organizational strategy for a course in logistics decision making is based on two organizing principles. The first is the principle of levels of elaboration where complexity, uncertainty, and time constraints rise with each level. The second organizing principle is a division of each level into two successive sections, where the first section is designed to accomplish Transition No. 1 in a CAI environment and the second section is designed to accomplish Transition No. 2 in a simulation environment. This macro strategy concept is presented graphically in Figure 14.

Figure 14. Macro Organizational Strategy for a Course in Decision-Making Skills (Strawman)



The next step prescribed by Reigeluth's ET is the sequencing of content within lessons and the integration into the lesson sequence of other components, such as summarizers, synthesizers, analogies, cognitive strategy activators, macro-level motivational components, and macro-level learner control options. Reigeluth's prescriptions for within-lesson sequencing are simple and logical. We intend to follow them (without repeating them here) by dividing each lesson into one or more segments, where each segment either provides instruction on a single idea or objective or represents a summarizer, synthesizer, cognitive strategy activator, analogy, or motivational component. Synthesizers, summarizers, and cognitive strategy activators will also appear as lessons (which will consist of a single segment).

4.4.3. Application: Micro Strategy

The next concern in defining organizational strategy is the micro strategy. Micro strategy concerns the organization of instruction within lessons and lesson segments and the organization of instruction within exercises. For the former, we rely primarily on Merrill's Component Display Theory (CDT) and on Gagné's nine events of instruction. For the latter we rely on the

dictates of functional realism and on the guidance gleaned from earlier analyses. We will first address micro strategy within lessons and lesson segments, then turn to a more detailed account of strategy within exercises.

Micro Strategy within Lessons and Lesson Segments. Instructional theorists appear to agree more on the elements from which to compose a micro strategy than on the elements that should be included in a macro strategy. Gagné and Merrill have each defined a rather comprehensive set of elements, either one of which has proved sufficient for the specification of micro strategies and for the design of effective and efficient instruction. Keller focuses on the motivational aspects of micro strategy and contributes several elements that are unique.

Our effort in defining micro strategy is guided by the dual purposes that the training system must satisfy (i.e., training as well as research). We are therefore interested in defining a comprehensive set of micro structure elements to enable the investigation of a broad spectrum of organizational strategy issues at the micro level. In other words, the objective here is not to define *the* definitive micro strategy; instead, the goal is to provide researchers with a "kit" from which they can construct a wide range of desired micro strategies.

In Merrill's CDT, micro strategy (strategy for a single objective) is first subdivided into the three successive "phases" of presentation, practice, and performance (i.e., testing). This scheme leaves out instructional elements that should occur prior to presentation, which other theorists (notably Gagné, Keller, and Ausubel) consider important. Therefore, it appears that an alternative "phase" scheme, which includes such elements, would be more comprehensive. The phase division suggested here consists of a **pre-instructional** phase, **instructional** phase, and **post-instructional** phase. The instructional phase includes Merrill's presentation and practice phases, and the post-instructional phase includes Merrill's performance phase. The types of instructional micro elements that are either mandatory or optional components of each phase are shown in Table 11.

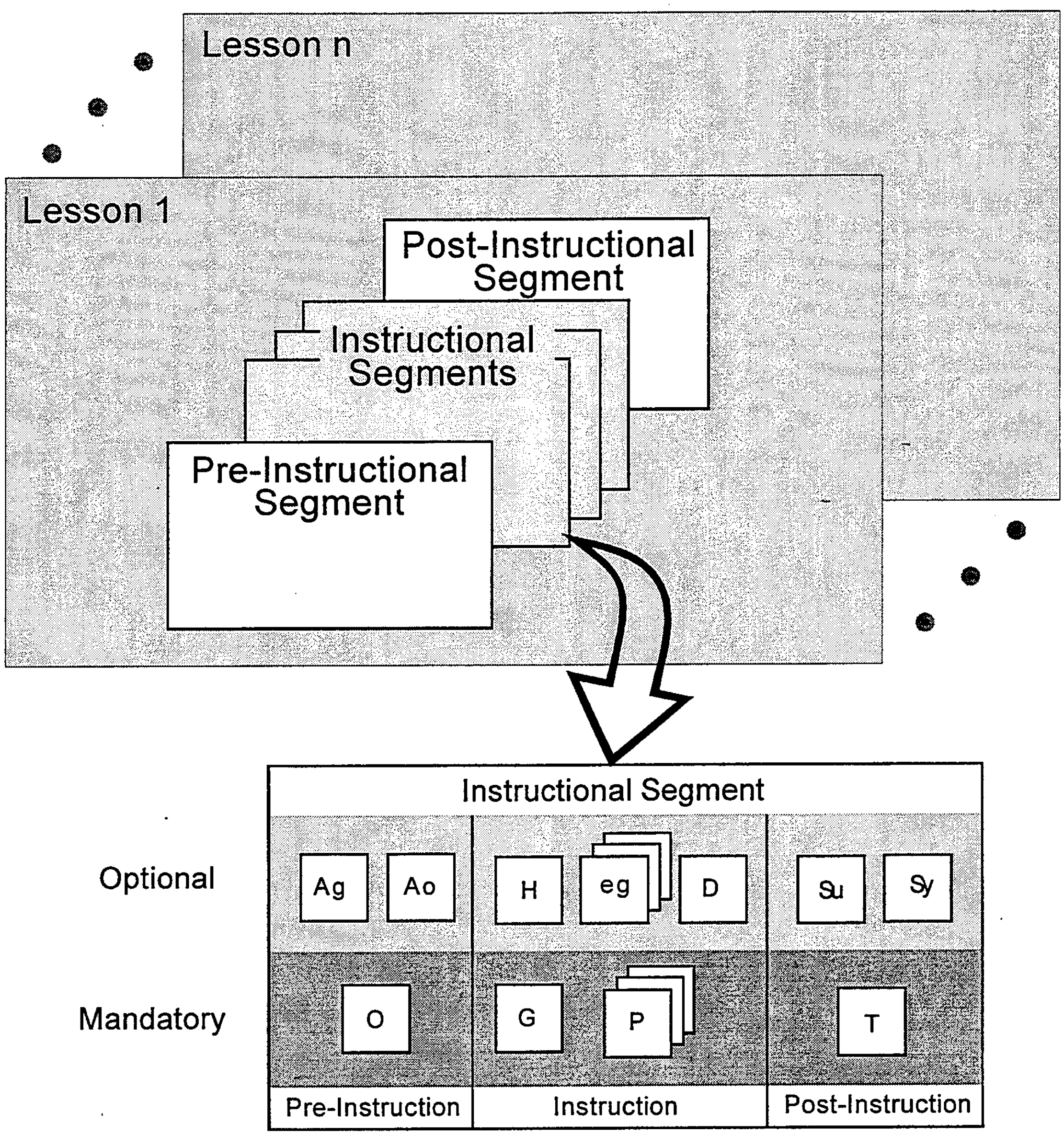
Table 11. Micro Strategy Elements

Phases and Elements	Code	Option	Function	Theory Support
PRE-INSTRUCTIONAL PHASE			Prepare student for instruction	
Attention Grabber	Ag	yes	Get the student's attention	Keller, Gagné
Advance Organizer	Ao	yes	Provide cognitive scaffold	Ausubel
Recall Stimulator	Rs	yes	Activate memory of prerequisite knowledge and skills	Gagné, Keller
Objective	O	no	Direct attention to desired outcome	Gagné, Keller
INSTRUCTIONAL PHASE			Instruct student	
Generality	G	no	Provide the information required to learn and/or control the desired performance	Merrill, Gagné
Help	H	yes	Facilitate acquisition and/or retention of generality	Merrill, Gagné
Example	eg	yes	Facilitate acquisition and/or retention of generality	Merrill, Gagné
Demonstration	D	yes	Facilitate acquisition and/or retention of generality	Merrill, Gagné
Practice and Feedback	P	no	Elicit the performance and provide feedback	Merrill, Gagné
POST-INSTRUCTIONAL PHASE			Solidify results of instruction and evaluate success	
Summarizer	Su	yes	Facilitate retention of generality	Reigeluth
Synthesizer	Sy	yes	Facilitate connections to prior learning	Reigeluth
Test	T	no	Evaluate the results of instruction	Merrill, Gagné

Whether a particular element should be included in a micro strategy and the specific content and form that each micro element should take is, in all instructional design theories, a function of the instructional objective that is to be achieved. We advocate a strawman that relies on the guidance provided by Merrill and Keller; at the same time, it should be made clear that the ultimate choice of strategy and the authoring of the individual elements must remain the prerogative of the researchers who will use the system.

The micro-level organizational strategy within lessons and within lesson segments is illustrated in Figure 15. The figure shows a three-phase organization on the segment level and within segments. The sequencing of segments within a lesson and the sequencing of elements within a segment is determined by management strategies. In general, sequencing will be driven by prerequisite relationships, degree of learner control, and student achievement.

Figure 15. Micro-Organizational Strategy within Lessons and Lesson Segments



Micro Strategy within Exercises. The simulation provides scenario-based exercises that afford students the opportunity to apply the knowledge and skill acquired via CAI to the solution of decision problems. The degree to which these skills will transfer to actual job situations depends first of all on the functional realism of these exercises; it does not depend on how well the exercises capture the physical details of any environment in which the target "Demand and Supply" problem occurs, but on how well they capture the underlying, common or general, functional details. The degree to which these exercises are instructionally effective and efficient

(i.e., the degree to which they support the acquisition of decision-making skills) will depend on the degree of instructional control that can be overlaid on these exercises.

The requirements for functional fidelity can be satisfied by providing a simulation based on a model that represents a composite functional abstract of the real domains to which the skills acquired in our training system are intended to transfer. Whether Air Force trainers and trainees will accept the simulation depends on how obvious the relationship of the simulation is to the jobs they have to train for (i.e., the simulation must be an obvious functional analogy, especially since it cannot be an obvious physical analogy). Thus, from the perspective of system designers of the system, the simulation must be so designed that decision problems are presented to the decision maker by the same kind of stimuli as in the real world (i.e., by messages arriving over various channels of communication). Furthermore, the decision problems in an exercise must have the same uncertainty and time line characteristics as real-world decision problems and the decision maker must have access to the same types of information resources to reduce uncertainty as are available in the real world. It also means the same types of noise and distractions must occur during decision making as in the real world, and whatever feedback occurs in the real world also occurs in kind and with the same timing in the simulation.

The requirements for instructional control are dictated by two factors. First, it will be necessary to control exercise difficulty and/or complexity in parallel with the levels defined by the macro strategy. Second, it will be necessary to control the insertion of instructional elements designed to facilitate the acquisition of the various types of meta-skills for decision making.

Control of exercise difficulty, or more precisely, control over the difficulty of the decision problems presented to students during an exercise, can be achieved by manipulating the type as well as the amount of uncertainty in each problem, the timing of the decision phases (e.g., by making the decision window shorter), the density with which decision problems occur in a given time frame, and the amount and types of distractions introduced into the exercises. These four types of control must be available, whether or not researchers decide to train meta-content (i.e., whether the instructional treatment will include explicit instruction in the time line model, the uncertainty model, and the process model). Thus, researchers who will use the system will need an interface that allows such control, and the system designer must build the system to satisfy these control and interface requirements.

Finally, control over the insertion of instructional elements associated with explicit training of meta-skills must be available to the researchers; therefore, it must be "designed into" the system by the system and instructional engineers.

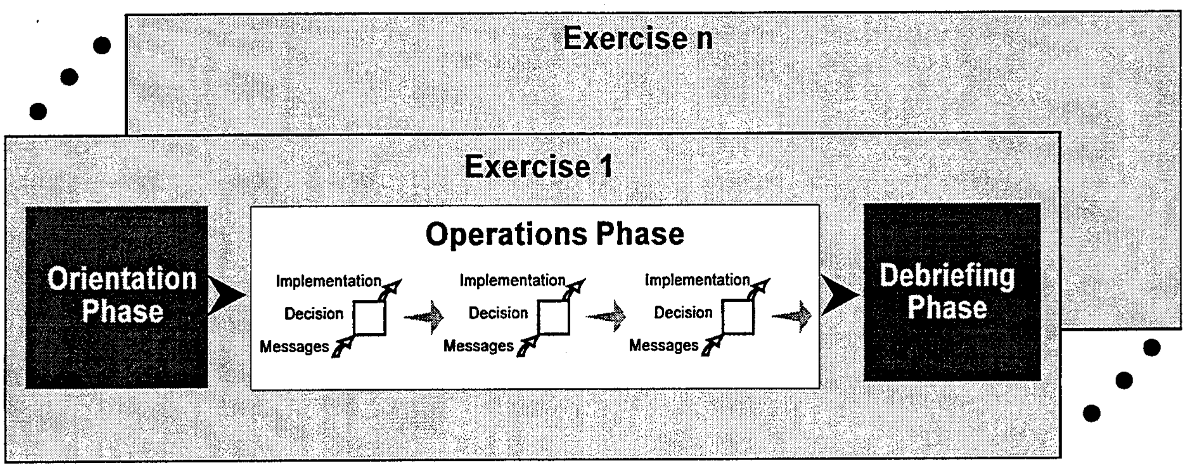
The preceding discussion demonstrates that instructional strategy within exercises (and on the macro level between exercises) must be a function of considerations arising from the combined needs for functional realism and instructional control. Both of these needs are considered in the discussion below, where instructional strategy is described from the point of view that an exercise should represent what decision makers do as they "pull a shift" in their assigned position. This is essentially the concept around which SuperKEATS, the predecessor system, was built, and (for lack of concrete information about domains other than the Air Support Operations Center (ASOC)) this is the currently operative concept for the exercises.

Exercises are divided into three phases: each exercise starts with an **Orientation Phase**, moves into an **Operations Phase,** and concludes with a **Debriefing Phase**. The orientation phase mirrors the start of the shift, the operations phase mirrors the remainder of the shift, and the debriefing phase mirrors nothing that occurs in reality. (The debriefing phase is dictated by the instructional need for artificial feedback.) This tri-partition, illustrated in Figure 16, constitutes in effect the micro organizational strategy for exercises. Below this level, more detailed organization is essentially determined by the requirements for functional realism. In the following paragraphs, these functional requirements are described for each exercise phase.

During the **Orientation Phase,** battle managers commonly receive a "shift briefing," and they bring themselves up-to-date by studying the latest available information. The orientation phase includes a reassessment of the situation and modifications to the existing plans of action. The information resources available for this phase are briefings, orders, status boards, and message logs.

The instructional strategy for this phase must present students with an array of information resources, very similar to those that occur in reality. Students should be able to browse these sources over a time span that could be limited. Students should then have access to a situation assessment (SA) and a plan of action (PA), either of which should be modifiable. Students can (but must not) receive immediate feedback regarding the modifications they make. All information resources as well as the original SA and PA are scripted during exercise development. The complexity for these items must be controlled either by scripting guidelines or by designing different templates for different levels.

Figure 16. Micro-Organizational Strategy within Exercises



The **Operations Phase** is entered after the time limit for the Orientation Phase expires or after students have finished orienting themselves. During this phase, the logisticians receive messages to which they must react. Some of these messages are demands for resources from operational units (i.e., from resource users), others are replies to messages sent out, and still others inform the battle manager of changes in the status of either resource users or resource pools (see Figure 13) or of changes in operational plans. Finally, some messages are totally irrelevant.

The demand messages trigger decisions on whether to refuse or accept the demand, on the priority in which the demands will be satisfied, and on the optimal methods to satisfy the demands. To make these decisions, logisticians must reduce secondary uncertainty within the available decision window by consulting available information resources. Typically, these resources include status boards, other members of the battle staff, reference materials, and agencies outside the battle staff. Once the decision is made, it is implemented by sending messages that usually go to resource pools as well as to the resource users who issued the demand. Reply messages typically provide information that must be "worked into" an ongoing decision process. Status and plan change messages either trigger updates to status boards or modification of the SA and PA. Irrelevant messages are ignored. The environment in which these activities occur can vary from completely quiet to extremely distracting and noisy. The density with which messages arrive can be anything from "once in a while" to "hot and heavy" (i.e., the task load can vary over a wide spectrum).

The instructional strategy for this phase must, at a minimum, mirror these conditions. Messages of all types must be presented to students in proportions and densities that are controllable. In SuperKEATS, density was controllable by scenario scripting (e.g., operational units that had superior strength compared to opposing forces requested air support less frequently) and by changing the exercise clock (real time, twice real time, or 10x real time). Information resources of various types must be available for consultation and, finally, message forms for sending out messages must be available. Noise and distracting information must be presented in a controllable manner.

These strategy elements are dictated by the requirement for functional fidelity. They must be complemented by elements arising from the need for instructional control over the presentation of both domain and meta-content. What students do in an exercise is basically practice. All the stimuli and resources required for appropriate practice in domain skills are already supplied by satisfying the requirements of functional fidelity -- that is, all but one: feedback. Feedback, as indicated previously, is a critical issue because it is an essential instructional element; however, immediate, a priori feedback (the most useful type) is relatively difficult to provide. During the Operations Phase, feedback should be available immediately after a decision is made, and such feedback should provide evaluation and corrective aid with regard to the solution of the decision problem itself and with regard to performance in terms of the underlying model of decision making (if meta-content is taught explicitly). This type of feedback must be artificially introduced and must be controllable in terms of content so as to permit fading during later stages of learning as the student moves increasingly toward the recognition-based decision mode. "Natural" feedback occurs as a consequence of the changes introduced into the domain by the implementation of decisions. This type of feedback is confounded with the effects of other factors, usually delayed and difficult to attribute to a specific decision. Nevertheless, it is feedback, it is unavoidable, and decision makers pay attention to it. Therefore, as the system design progresses, we must be attentive to opportunities to make such natural feedback more useful.

In addition to feedback, other types of instructional elements can be introduced into exercises and should be available as means to manipulate the instructional strategy. One type, which was used in SuperKEATS, consists of **suggested solutions** to the decision problem at hand. Another type are **prompts** of various kinds to direct students' attention to salient features of the current decision problem to provide some degree of assistance. Such assistance can

address domain content concerns, meta-content concerns, or both, and it may be introduced during early stages of the learning process and faded as the learner's performance improves.

A particularly interesting type of learning assistance may be provided by using immediate, a priori feedback as a device to improve decisions prior to implementation. In this mode, students would input a decision, then choose to have it evaluated before committing themselves to it (and before the system works it into the situation). If the feedback from the evaluation indicates problems with the decision (either by a low score on some parameters or by pointing to specific deficiencies), students could then modify their decision until feedback is satisfactory. This "**exploratory optimization**" would provide the student with a unique opportunity to explore and try out specific variations prior to making a commitment to a particular decision. This type of learning assistance not only highlights the role of commitment but also provides instant remediation for gaps and misconceptions in the learner's current knowledge base. If this mode is used, it should be used during early stages and initially without time constraints. As the learners progress, time constraints can be introduced so that they can do all the exploring they want up to the default point. During later stages, the mode should be withdrawn entirely.

The **Debriefing Phase** is purely an instructional device. During this phase, learners receive cumulative feedback on the entire exercise, from its start to its termination. This feedback should address three issues: (1) set of "bean counting" scores that indicate how well the battle went for the decision maker's side; (2) statistics on how many decision problems were presented, how many decisions were actually made (and on how many the student "dropped the ball"), and the quality of those decisions; and (3) statistics that indicate how well the student performed in terms of meta-content (i.e., was uncertainty reduced in the right priority? Were the appropriate information resources accessed? How many decisions were made before and after the default point? How long were recognition times? etc). Only the first type of cumulative debriefing feedback was used in SuperKEATS.

V. CONCLUSIONS

The objective of this report was to lay the theoretical foundation for a research project dedicated to the development of an optimal training methodology for decision-making skills in the arena of LC^2. A training methodology is fully specified when organizational, delivery, and management strategy are defined (Reigeluth, 1983). The delivery strategy for the project was prescribed in general terms as a computer-based training system that can run on common desktop machines without the assistance of instructors. Therefore, development of a theoretical foundation had to address the issues of organizational strategy and management strategy under the constraint of a prescribed delivery strategy.

Organizational macro and micro strategies for a desktop-computer-based training system were defined by conducting analyses which examined four topics in order:

- What is decision making?
- How do people make decisions?
- How do people learn to make decisions?
- What direct instructional design guidance is available?

The analyses produced a coherent and cohesive theoretical framework based on the concept that decision making is, in essence, an uncertainty reduction task that requires commitment to a course of action in the face of unavoidable, residual uncertainty. A series of models was developed that describes the nature of the decision-making task, the process of uncertainty reduction, and the process of learning decision-making skills. Instructional design guidelines were deduced from the models and from other available guidance uncovered by the analyses. The guidelines were then applied to the training problem at hand, and a complete general organizational strategy for the desktop training system was developed.

Instructional and system design and development will lead to a concrete training and research system. The system will be loaded with a baseline training program. The baseline training program will feature an artificial logistical domain (a space-based, science-fiction-like context), and it will be organized along the organizational strategy developed in this report. It will also incorporate a baseline management strategy consisting of a level of learner control and

advancement criteria. Both strategies, organizational and management, will be modifiable for research purposes.

The primary purpose of empirical research will be to optimize the training methodology and to provide a basis for generalizability to other decision-making domains. Two significant research issues have already been mentioned: the issue of meta-content and the issue of transfer from an artificial domain. However, these are by no means the only issues that will have to be investigated. Table 12 lists a number of important research issues. This list is provided with the caveat that it is not and cannot be complete or exhaustive at this point; it is essentially a "starter list." New issues will undoubtedly arise during the development of the system and, especially, as actual research gets underway.

Table 12. Starter List of Research Issues

No.	Issue Title	Type	Research Questions
1	Artificial Domain	Content	To what extent does decision making in a real domain benefit from training in an artificial domain where the same types of problems are solved?
2	Meta-content	Content	Does the inclusion of meta-content increase training effectiveness and/or efficiency? What type of meta-content is most helpful?
3	Macro Partitions	Organization	What is the optimal number of elaboration levels for given entry and exit skills?
4	Learner Control	Management	What are the effects of various levels of learner control on training effectiveness and efficiency?
5	Presentation Form	Content Form	Does the form of content presentation affect training effectiveness?
6	Facilitative Elements	Organization	What are the effects of including facilitative elements on student achievement and instructional efficiency?
7	Feedback Forms	Organization	What are the effects of a priori feedback, a posteriori feedback, or combined feedback on student achievement and instructional efficiency?
8	Exploration Practice	Organization	Can forms of exploratory practice increase student achievement and/or instructional efficiency?
9	Criterion Levels	Management	Where should one set the criterion levels for student advancement (to the next segment, next lesson, simulation practice, the next level) for the optimal compromise between effectiveness and efficiency?

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APPENDIX A. CHARACTERISTICS OF THREE TYPES OF DECISION-MAKING TASKS

Decision Problem Characteristics	Case 1 Taxicab Dispatcher	Case 2 Supply Logistician	Case 3 Car Buyer
Starting Situation	Customer calls cab company X. Needs cab to airport 20 miles from his house; must be there by 6:50. It is now 6:00 a.m. Current traffic density means the trip will take 30 minutes (i.e., the customer must be picked up by 6:20). The dispatcher (D) is busy with 20 cabs en route, five cabs sitting at airport, two cabs sitting elsewhere.	Supply logistician (L) receives request: squadron in Saudi Arabia needs several spare parts for aircraft within five days. Severe operational impact if they do not get the spares. No spare part shortages stateside. No requests from other units for the same types of parts. Constant flow of air and sea transports to theater ongoing. Plenty of available transport capacity. No en route threats.	Single buyer who has an old car (a truck). Car now in the shop more than on the road. Heavy bills. Has decided to buy a new car but does not know what she wants, although she believes she does not want a truck again. Unfamiliar with market. Can buy up to 45K worth of car without strain.
Decision to be Made	D must decide which cab he should dispatch.	L must decide which of several possible supply solutions he will implement.	Car buyer (CB) must decide which car she will buy.
Time Line Aspects			
Length of Decision Window	Seconds, minutes	Hours, days	Weeks, months
Recognition Process (OCP - RP)	OCP occurs when the customer starts talking to D. RP occurs when D recognizes the call is a transportation request he must deal with. Recognition time is largely dependent on how quickly the customer gets to the point (e.g.: "Is this the X cab company? Who am I talking to? My wife drove the car yesterday, and I don't know what's wrong with it, but today the darned car won't start and I have to fly to Podunk today..." versus "I need a cab to the airport!").	OCP occurs when the squadron's request arrives at L's office. RP occurs when the request is being read by L and L recognizes he needs to deal with it (and that he can neither toss it or hand it off). Recognition time is highly dependent on how many other messages are waiting for L's attention, on how many other things he is attending to at the moment, and on how organized he is.	OCP occurs when the cost of maintaining the old car begins to exceed the cost of owning a new car. RP occurs when CB realizes that fact. (OCP may also occur when CB just gets tired of the old car and wants something new. In that case, RP occurs when CB realizes she cannot go on carrying her desire around with her, that she has to do something about it.) In either case, the OCP and the RP are probably not very distinct moments in time; rather, they just "creep up" on CB.

Decision Problem Characteristics	**Case 1 Taxicab Dispatcher**	**Case 2 Supply Logistician**	**Case 3 Car Buyer**
Uncertainty Reduction Process (RP-DP)	Uncertainty reduction is usually achieved within a single working period. The length of that period is most likely less than one minute. The DefP is reached prior to 6:20, when even the closest free cab cannot get to the customer pickup on time.	Uncertainty reduction is usually achieved over several working periods, lasting several minutes each. These periods are usually separated by longer intervening work suspense periods during which other high-intensity tasks are accomplished. The entire evolution from RP to DP may take a day or two of elapsed time and one or more hours of working time. The DefP is reached when the time to send parts exceeds the time left to the five-day deadline.	There are two basic possibilities: the rational approach or the impulse approach. The rational approach is a long, protracted process with numerous work episodes that may last anywhere from minutes to hours. The impulse approach circumvents the labor of uncertainty reduction in favor of instant gratification. The DefP for this case (with either approach) is an indistinct, or "creeping" point, unless the old car suddenly expires totally.
Implementation Process (ISP-IFP)	There is no implementation delay and implementation itself takes as long as a radio call to the selected cab (i.e., seconds).	There may be implementation delays due to "approval" requirements or communication outages. Implementation is accomplished by messages which take minutes to compose and transmit.	There can be implementation delays (due to hesitation) lasting days, weeks, or even months. Implementation can take a long time (car availability, loan approval).
Feedback Process (FSP-FFP)	Feedback (call from cab departing customer location) will come in within minutes after implementation. D must stay on it because the dispatched cab may have problems and a new cab may have to be tasked. Feedback ends with a definite message of customer delivery at airport.	Feedback is not a sure thing in this case. L may never receive any confirmation that anything is underway or that anything has gotten to the destination. He can, however, solicit/access such feedback information. L usually does spend a good deal of time answering requester queries as to just where the shipments are in the pipeline.	Feedback is instantaneous and certain and usually quite definite. It starts when CB drives the car off the dealer's lot and continues until she gets rid of it.
Uncertainty Reduction Aspects			
Overall Magnitude of Uncertainty	Low	Medium	High

Decision Problem Characteristics	Case 1 Taxicab Dispatcher	Case 2 Supply Logistician	Case 3 Car Buyer
Situation Uncertainty (Us)	Clear situation (i.e., very low or zero Us). The dispatcher is "on top of it" and knows how many and what kinds of demands he has pending, how many cabs he has moving in various areas of the city and how many he has sitting, and where and what the traffic situation is along major routes.	Clear situation (i.e., very low or zero Us). The requirement or need is very clear and specific, the supply and transportation situation is well known, and the consequences of not satisfying the requirement are known.	Some Us. CB is aware of the high current maintenance costs but does not know for sure whether owning a new car would be cheaper.
Goal Uncertainty (Ug)	Clear goals (i.e., very low or zero Ug). Get the customer to the airport on time and with a minimum of unpaid mileage. D knows exactly what he wants to achieve.	Clear goals (i.e., very low or zero Ug). L knows exactly what is to be accomplished ("Get the stuff to the unit ASAP, but no later than five days from now!").	Very vague goals (i.e., very high Ug). CB wants a "new car" that is not a truck but beyond that has not yet determined whether she is looking for a particular type of car, whether she wants to maximize reliability; minimize price; maximize comfort, looks, or performance; etc.
Option Set Uncertainty (Uos)	Relatively high Uos. This is the primary area on which D needs to work. He knows the two basic option classes for this problem: Option Class 1: Use an "en route cab" that is near the customer location; Option Class 2: Use a sitting cab. He needs to identify specific options for at least one of the two classes.	Relatively high Uos. L knows basic option classes for this type of problem: Option Class 1: Normal sourcing and air transport; Option Class 2: Lateral sourcing in theater, followed by resupplying lateral source if required. He does not have specific options in either class to start with.	Very high Uos. CB knows there is a bewildering array of options out there, but she can not yet cut this "options overload" down to manageable size.
Option Feasibility Uncertainty (Uof)	Some Uof. D knows that feasibility for Option Class 1 is much better than for Option Class 2; Cabs in the area have a much better chance of making the pickup deadline. But he knows nothing about feasibility of specific options because he has none as yet.	Some Uof. L knows that Option Class 1 has generally better feasibility than Option Class 2. He relegates Class 2 to "fall-back options" status. Will have to work on Uof for each specific option.	Very low to zero Uof. CB knows she can buy anything up to 45K (i.e., she can implement a very wide range of options).

Decision Problem Characteristics	Case 1 Taxicab Dispatcher	Case 2 Supply Logistician	Case 3 Car Buyer
Option Effects Uncertainty (Uoe)	Some Uoe. D knows the effects of options from Class 1 are better than the effects of Class 2 options. Cabs in the area have a much better chance of getting to the customer with a minimum of unpaid miles. But he knows nothing about effects of specific options since he has none as yet.	Some Uoe. L knows that Option Class 1 has more desirable long-term effects (more supplies in theater) and that Option Class 2 has good short-term effects (early availability of spare parts). Might have to work on Uoe for specific options if feasibility issues are not decisive.	Very high Uoe. Since she does not know what she wants to achieve and has not yet narrowed her huge option set, cannot determine what buying a new car will do for her, except reduce her current maintenance bills and increase car availability.
Uncertainty Reduction Strategy	D needs to first identify specific options for the preferred class (i.e., he needs to reduce Uos before anything else). Hence, he will radio a call: "Is anyone in such-and-such an area?" If he gets only one response, he needs to find out whether that driver can indeed take this fare (i.e., he needs to reduce Uof). If he gets more than one response, he will have to determine who can take the fare and who is closest (i.e., he needs to reduce Uof first, and then further discriminate by reducing Uoe).	L needs to identify a specific option for the preferred class and reduce Uof for that option as much as possible. If he can achieve a high level of confidence that the option is feasible, he can implement that option without putting a fallback option from Class 2 on standby. If feasibility remains uncertain, he should implement with fallback.	CB needs to start with Ug by setting some clear goals (e.g., "I want a car for getting around town and for little weekend trips. It should be economical first, comfortable second, and look good third. It should seat four people and a weekend's worth of luggage for two."). That will have the effect of reducing the huge option set to four-door sedans under 45K, enabling her to define a manageable set of options. She can then reduce Uoe for each option based on her three criteria and end up with a rank-ordered list. The first car on the list is the rational decision.

APPENDIX B. ACRONYMS

AFHRL	Air Force Resources Laboratory
AL/HRTC	Armstrong Laboratory, Human Resources Directorate, Technical Training Research Division, Instructional Design Branch
AFLC	Headquarters Air Force Logistics Command
ALC	Air Logistics Center
ASOC	Air Support Operations Center
C^2	Command and Control
CAI	Computer-assisted Instruction
CB	Car Buyer
CDT	Component Display Theory
CINC	Commander-in Chief
D	Dispatcher
DefP	Default Point
DP	Decision Point
DS	Demand and Supply
ECM	Electronic Counter Measures
ET	Elaboration Theory
FFP	Feedback Process
FSP-FFP	Feedback Process
HQ USAF/LGX	Air Force Logistics Plans and Program Directorate
HR	Air Force Human Resources Directorate
ID	Instructional Design
ISD	Instructional Systems Development
ISP-IFP	Implementation Process

KR	Knowledge of Results
L	Logistician
LC^2	Logistics Command and Control
OCP	Objective Choice Point
OJT	On-the-job Training
PA	Plan of Action
PC	Personal Computer
ROC	Rational Outcome Calculation
RB	Recognition-Based Decision Making
RMK	Reigeluth-plus-Merrill-plus-Keller
RP	Recognition Point
RP-DP	Uncertainty Reduction Process
RPD	Recognition-Primed Decision
SA	Situation Assessment
SEA	Systems Engineering Associates
TC^2	Tactical Command and Control
UMSA	Unified Model for Skill Acquisition
USAF	United States Air Force
U_S	Situation Uncertainty
U_G	Goal Uncertainty
U_O	Option Uncertainty
U_{OS}	Set Completeness Uncertainty
Uos	Option Set Uncertainity
U_{OE}	Effects Uncertainty
Uoe	Option Effects Uncertainty
U_{OF}	Feasibility Uncertainty
Uof	Option Feasibility Uncertainity